The Effects of Noise Upon Certain Psychological and Physiological Processes

BY
FRANCIS L. HARMON

ARCHIVES OF PSYCHOLOGY
R. S. WOODWORTH, Editor
No. 147

ARCHIVES OF PSYCHOLOGY

COLUMBIA UNIVERSITY, NEW YORK CITY

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NEW YORK
February, 1933

FOREWORD

I wish to express my deepest appreciation to Professor A. T. Poffenberger, of Columbia University, for his unfailing encouragement and constructive criticism throughout the course of this research; to Dr. George H. Rounds, of Columbia University, for his invaluable services in performing the gas analyses upon which depend the metabolic rate determinations; and to Mr. E. E. Edelman, of Columbia University, who served as subject in one series of experiments. For the noise apparatus used in the investigation, I am indebted to the E. E. Free Laboratories, Inc., of New York City. Finally, for her painstaking assistance in the preparation of the manuscript, for her sympathetic understanding of the difficulties involved, and for her confidence and encouragement, it is my privilege to thank, above all, my wife.

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I. Introduction

The publication in 1930 of the New York City Noise Abatement Commission's report on *City Noise* was an important event in the study of this problem. It marked the awakening of a wide-spread popular interest in a question which has for many years interested scientific workers in the fields of psychology, physiology, and medicine: the question of the effects of noise upon the human organism.

In what way, if at all, does the organism react to stimulation by sounds? Is the effect dynamogenic or otherwise? Does the body respond with an increased output of energy; with a decreased output, or does it remain unaffected? If the energy expenditure is increased, does this result in greater efficiency, or is this extra energy used up in overcoming the distracting effects of the noise? These are only a few of the problems which at once confront the investigator who enters this field.

As a problem in experimental psychology, noise has occupied a prominent place since the days of Wundt and his students at Leipzig. There the studies of distraction grew out of the old reaction-time experiment, and were carried into the investigations of the more purely "mental" processes: attention, reasoning, etc. Another and an older aspect of the problem which has been taken over largely from physiology, is the effect of various kinds of noises upon such processes as the heart beat, blood pressure, respiration, and the like. More recently has come the question of its effects upon "general efficiency," as in the case of office workers, for example.

In the experiments which we are about to describe, we have approached the problem of noise from the standpoint of physiological psychology. Recognizing the importance of the relationship between psychological and physiological processes, we have sought to take a complete and well rounded view of our problem. In connection with measurements of mental activity, we have traced and measured, so far as it lay in our power, some leading physiological concomitants of this activity, namely, energy metabolism, respiration and heart rate. With the aid of these, we have sought to compute the effects of noise on the efficiency of our subjects while solving simple problems in addition. By means of the latter we

obtained an exact measure of output, while the former yielded good indications as to the energy expenditure.

Our procedure involved the collection of "control" data on days when no noise at all was present to serve as a basis of comparison for the results which were obtained on days when noise was used; and the differences observed have been attributed to the effects of the noise. Moreover, by continuing our experiments over a sufficiently long period of time, we were able to follow certain changes which took place in these differences themselves, and these changes mark the course of our subjects' adjustment to the noise stimulation.

Thus our aim in this investigation has been two-fold: first, the study of the immediate effects of certain kinds of noises upon individuals engaged in mental work; and second, the tracing of any possible adjustment or adaptation on the part of the subjects when the experiments are extended over a period of weeks or months. This, of course, involves the presentation of rather detailed and extensive day-to-day results; and in this respect as much as in any other, lies the greatest advance of this study over other investigations dealing with the energy cost of noise.

II. Review of the Literature

Investigations dealing with the effects of various kinds of noises upon individuals have been as varied as the interests and points of view of the investigators themselves. In the majority of the earlier studies, however, the interest centered around some one particular aspect of the problem, such as the subjective effects of noise, the effect of noise upon reaction-time, upon heart rate, and the like, with little attempt to relate these changes to the more fundamental changes occurring in the organism.[1]

In the present review we shall confine ourselves to the few, comparatively recent studies which have been carried out from viewpoints closely approximating our own; namely that the effects of noise are more wide-spread than any single process within the human organism, and that the ultimate solution of the problem is to be arrived at not through the study of output alone, but through the investigation of concomitant energy expenditure or "cost" of the work, and the relating of "cost" to output.

The earliest, and probably the most systematically planned of all the experiments of the type we have just described, was performed by Morgan in the Columbia laboratory in 1916 (25). Morgan was interested in investigating the effect of noise upon a complex mental process, which was not susceptible to a great deal of improvement through practice, and which required constant attention on the part of his subjects.

To this end Morgan constructed an apparatus which involved the translation of letters into numbers by means of a complex code which was exposed to the subjects. They responded to the exposure of a given letter by glancing at the code before them and pressing the proper key of a typewriter, specially adapted for the purpose. Each subject worked at the task for an hour's sitting, and records of reaction-time, errors, breathing, and the force with which the keys were struck, were taken. The last-named Morgan considered his most reliable measure, inasmuch as it was taken without the knowledge of any of his eight subjects.

Nine different sources of noises were used in the experiment, including bells, buzzers, and hammers of all kinds; an eight-inch fire gong; and a set of phonograph records. These sounds were used singly and in various combinations throughout the noisy

[1] An excellent review of all the literature bearing upon the general problem of the effects of noise was published by Diserens in 1927 (9).

periods, which were interpolated between intervals of quiet during a given sitting.

As mentioned, eight subjects served in the investigation. The time records showed that when the noises were first introduced, they caused a retardation in the speed of the work. This slow period, however, was followed by an acceleration; and in some cases the subjects even exceeded the speed they had made during the quiet periods. When the noises ceased, a second retardation occurred; and similar results were obtained in other noisy periods.

The records of errors made by the subjects revealed nothing of significance, as the errors, both before and during the noise, were too few to mean anything. At any rate, the noises had no adverse effect upon the quality of the work done.

Morgan's data on the breathing of his subjects during the experiment were highly interesting. Breathing curves were taken continuously, by means of a pneumograph, and I/E ratios were computed. It was found that marked changes in these ratios occurred during the noisy periods; and examinations of the breathing curves, as well as the observations of the subjects themselves, showed that articulation was being used in an effort to overcome the distraction. In most cases this device was not hit upon at once, but usually appeared for the first time at about the middle of the noisy periods.

The key-pressure records showed very definitely that the subjects struck the keys with considerably more force in a noisy than in a quiet situation. At the end of the noisy periods, moreover, the key-pressure dropped once more to "normal."

These last findings throw a great deal of light upon the nature of the whole problem of noise. Were we to consider only the records for output, speed, and accuracy, we would be tempted to say that the noise produced a beneficial effect, or no effect at all upon the subjects. The breathing curves, however, show that there was a definite disturbance present, to overcome which the subjects made use of the device of articulation; and the disturbance is further indicated by the higher tension under noise, as shown in the key-pressure records. In other words, the noise did offer a distraction, and to overcome this, the subjects threw themselves with more force into the task in hand. The implication is that we cannot judge of the effects of noise by output alone, for this may remain unaffected, or it may even be increased; in order to get a true picture of the

process, we must investigate the energy expenditure of our subjects during the distraction.

Morgan found that the changes due to different kinds of noises were of less importance than the general fact of adjustment to any kind of distracting situation. It matters little, he thinks, what the nature of the noise may be: the important thing is that it presents a disturbing situation which must be overcome in order to progress; and the way in which it is overcome is the same in all cases.

Finally, the correlation among the various measures was found to be very low. This would indicate again that each of the processes studied is largely independent of the others, and that, therefore, no ultimate solution of the problem can be obtained through the investigation of a single isolated aspect of it.

In 1917, Morgan (24) reported another study of the effects of noise, this time upon memory. He experimented with paired associates (word-digit), presented visually to 20 subjects. The associates consisted of 10 pairs in a list, and four lists; two of which were presented during quiet, and two under noisy conditions. The apparatus by which the subjects responded was an adaptation of the one described by the author in his previous monograph on noise; and the following measurements were taken: learning records, correct responses and reaction-times; breathing curves; key-pressure; and tests of recall, retention, and recognition; these last being made two days after the main experiment. The noises consisted of a phonograph which was played continuously, a fire gong, and an electric buzzer, sounding intermittently.

The results showed an increase in errors during learning due to the noise; however, the noise had little or no effect upon the learning time.

Articulation, as shown by the breathing ratios, was used by the subjects in order to overcome the disturbing effects of the noise. The key pressure increased with the introduction of the noises, but more at the beginning than at the end. Retention, recall, and recognition were all less for the material learned under noisy conditions.

On the basis of all his results, Morgan concluded that material which is bare of associative bonds is best for testing the effects of distractors. He reiterated the importance of making tests without the subject's knowledge, so far as possible, feeling that when a subject knows that a given test is to be made, he will strive to excel in

that process; often going to the length of compensating for loss in one direction by sacrificing some other process.

Laird (22), in 1927, made a study of the physiological cost of noise, which he determined by the method of respiratory metabolism.[2] Laird's subjects were four professional typists, two men and two women. These subjects typed for two hours a day, over a period of four weeks, always working on the same letter, which was copied about 2,000 times during the course of the investigation. The noises consisted of an electric motor, ball bearings rotating in a hexagonal sheet-iron drum, an auto siren, and a telephone bell, all operating "intermittently and automatically."

When these sounds were operating in a small room with bare walls, we are told that it was "no noisier than many offices," though no numerical data are given on this point. When the walls were covered with acousti-celotex panelling, the noise was reduced "about 50 percent." These two conditions, then, were called the "noisy" and the "quieted" phases of the experiment, respectively. During the first week the subjects worked every day under the quieted conditions; during the next two weeks under the noisy conditions; and during the fourth week, under quieted conditions once more. For some unknown reason, no attempt was made to establish controls by having the subjects work with no noise whatever in the room; and this must remain a glaring omission in technique.

The procedure was as follows. The work began each morning at eight o'clock, when the subjects, after a "uniform breakfast," were conducted to the room in which the experiment was made. There they took their seats before noiseless typewriters, and donned the gas masks by means of which the exhaled air was collected for analysis. After a 30-minute rest period, the signal to begin work was given, and the noise was started. The work period itself lasted two hours. Samples of the exhaled air were collected every fifteen minutes, and these were compared with a sample taken at the end of the rest period. In addition to these data, speed and accuracy records were obtained, as well as introspective reports from the subjects.

The metabolic results, when expressed in calories expended per minute, showed an increase over the resting rate averaging 52 percent, when the noise was deadened by the panels; and an increase

[2] Reports on this same investigation have appeared also in the *Jour. Nat. Inst. Indust. Psy.*, 1929. 4, 251–8; and as a reprint in the N. Y. Noise Abatement Commission's monograph, *City Noise*, 1930, 296–301.

averaging 71 percent when the noise was not quieted. The average time for typing a letter was found to be 162 seconds under the quieted conditions. When the four subjects were ranked according to speed, individual differences with respect to the effect of noise upon typing rate were observed. These are shown in the table below.

Rank	*Increase in speed in quieted phase*
Slowest	0.0 percent.
Next	0.8 "
Second Fastest	3.6 "
Fastest	7.4 "

Apparently the differences in accuracy under the two sets of conditions were too slight to be significant, for no numerical data are presented on this point. Fatigue effects, however, were computed by averaging and comparing the time required for typing the first five letters and the last five letters in each experimental period. It was found that during the quieted phase, the subjects reduced the time 7 seconds; while during the noisy phase, the average time was increased 5 seconds by the end of the period.

Another interesting detail was brought out in this study, regarding the evidence for fatigue in the energy expenditure of the subjects. Had the noisy conditions proven more fatiguing than the quiet, one would have expected the differences between the two conditions as regards energy expenditure to increase towards the end of the sittings. As a matter of fact, these differences remained the same.

We have discussed this study at some length, first because the results are highly suggestive as to methods of attack on the problem of noise; and secondly because Laird has made use of the metabolic method in much the same way that we have used it in our own research. Laird's study, however, leaves a great deal to be desired in the way of procedure, as well as in the treatment and presentation of results.

In the first place, one is led to question seriously the adjustment of Laird's subjects to the experimental set-up, the apparatus, etc. As we shall show later, our own experiments have indicated clearly that a period of some weeks is necessary for the subject to become adjusted to the gas mask and the other paraphernalia in-

volved in making measurements of energy expenditure. During this period of adjustment, the values for resting metabolic rate are unduly high, and the results obtained at this time are not fair pictures of the processes themselves. For this reason, one wishes that this investigator had devoted a few weeks to adjusting his subjects to the experiment, instead of simply beginning with a week's run under the quieted conditions.

We have already mentioned the value of establishing controls by having the subjects work in a room with no noise whatever; and we have remarked that, in our opinion, this omission detracts from the value of the study. Another criticism of paramount importance concerns the absence of the day by day results. The literature of the problem shows that a subject's response to noise is a variable thing, and that, oftentimes, this response may differ in direction from one day to another. Moreover, the question of possible adjustment to the noisy conditions could be answered only by the tabulation of the results for each day, and comparing them with one another. In no case is the presentation of averages alone an adequate treatment of the data.

For these reasons, as we have already indicated, we can regard Laird's study as suggestive, and little more.

Ford (12), in 1929, studied the effects of noise upon 17 subjects who were doing problems in addition. The time required for solving each problem was recorded, as well as the writing pressure of the subjects. The noises were produced by a phonograph and an automobile horn.

The subjects added sums, about 6 each, under conditions of quiet, noise, and quiet again. Ford found an initial slowing up of speed per problem at the beginning of the noise, and again when quiet was restored. The change with the introduction of the noise was more pronounced, however. A correlation of .55 between writing pressure and "reaction-time" was also reported.

Since the completion of our own experiment, one other study dealing with the effects of noise upon mental work and metabolic rate has appeared. This study was published by Vernon and Warner (39), in 1932. These investigators, who were interested primarily in obtaining objective tests for measuring the effects of noise, rather than descriptive accounts of the processes involved, included in their research a brief series of experiments dealing with changes in the rate of oxygen intake accompanying noise.

Two subjects read or worked arithmetic problems during a two-hour period. The rate of oxygen absorption was calculated for each subject during an initial half-hour of quiet, during an intermediate hour when an electric bell was sounded intermittently, and during a final half-hour of quiet. It had been determined previously that speed of output either remained unaffected, or was slightly accelerated by the noise. As to the rate of oxygen absorption, it was found that when the subject was reading, the noise had no effect whatever; but when arithmetic problems were being done, the noise was accompanied by a 4 percent increase. From their results, the authors concluded that the most satisfactory test of the effects of noises is to be found in a rating by the subjects of the degree to which they were distracted.

The method used by Vernon and Warner to measure changes in oxygen absorption shows that these investigators were lax in their experimental technique, to say the least. In plotting curves, successive half-hour periods were laid out along an abscissa, and rate of oxygen absorption along the ordinate. When the curve was drawn, it showed a steady descent from beginning to end of the two-hour period. The authors attribute this fact to the lack of a sufficient rest period at the beginning of the experiment; and since the values for the first half-hour of quiet work were so high, they proceeded to measure the increases in oxygen rate from the final half-hour of quiet work. They neglected to plot a control curve using quiet conditions throughout; and they also neglected the possibility of adjustment to the noise on the part of their subjects.

In all the investigations which we have cited, there is agreement upon one point; that noise does raise the energy expenditure during mental work. The disagreement among the various investigators centers chiefly around the size and importance of these changes which accompany a noisy environment. Obviously the first step in answering this question lies in presenting detailed, day-to-day results, as well as averages; in taking into consideration not only the immediate effects of the noises, but also the possibility of adjustment to them; and lastly, in the measurement of as many processes as possible; and it has been on just these points that we have attempted to supplement the literature on the effects of noise.

III. Apparatus and Method

1. *Outline of the Experiment*

Our problem, simply stated, was to observe the effects of noise upon individuals doing mental work for a set period of time each day; and to investigate the changes produced by the noise in certain processes connected with this work.

Having adjusted our subjects to the apparatus and the general experimental set-up, we next proceeded to study the relationship between mental work and our physiological processes under normal conditions; *i.e.*, without noise. So far, our experiment dealt only with physiological changes during mental work; while, at the same time, we hoped to give the subjects sufficient training in the work itself, so that improvement would be slow after we had begun using noise.

Our next step was the introduction of the noise. This was made intense enough and arhythmical enough to constitute a real disturbance, from the point of view of annoyance at least; and indeed our noises may be said to have "filled" the room in which the subjects worked. Interpolated between the noisy periods were periods of quiet, for the purpose of control and comparison.

Having ascertained that our subjects were definitely affected by the noise, our course was now clearly indicated to us; namely, to extend the experiments over a sufficiently long time to observe the process of adjustment to the noisy conditions: or in other words, to see whether the subjects would continue responding in the same manner, or whether a change, either quantitative or qualitative, would take place in their responses. The tracing of this change now became our chief concern.

Throughout we have recognized the necessity of fractionating our data in the treatment of results. This applies not only to days and weeks, but also to individual sittings. Experience (our own as well as that of others) has shown beyond a doubt that in dealing with material of this kind, the variability of a given individual is so great as to render averages alone misleading. A careful study of the raw data is essential to any true understanding of the results.

2. *Description of the Processes and their Measurement*

Addition was selected as the mental task to set before the subjects. We used three-place numbers, ten to a problem. In order to avoid repetition of number sequences in the construction of our sums, we took numbers from the New York Telephone Directory, using the last three digits of each combination. This did not include zeros, which we avoided in making up our problems.

One hundred and twenty sums were composed and typed on filing cards, 3 by 5 inches in size. Only one sum occurred on a card. At the beginning of each day's experiment, these cards were thoroughly shuffled, and set upon the table before the subject. He picked them up, one at a time, added the sum, wrote the answer on a strip of paper taken from the roll of an adding machine, and passed on to the next problem. The answers were thus written, one below the other, on a long strip of paper, the end of which was soon out of sight of the subject, who at best could have only a vague idea as to how many he had done. The instructions were always to work at top speed.

It may possibly be objected that even under these conditions, the subjects would in time learn the answers to the problems, since their number was, after all, still limited. Such, however, was not the case. In the first place, the cards were mixed at the beginning of each experiment. This effectually prevented all chances of memorizing the order of presentation of the sums. Moreover, the number worked on any day never exceeded 90, which left 30 comparatively new sums to be distributed, at random, among the others. Under these conditions the subjects reported a sort of vague feeling of familiarity with some of the problems: a feeling that they had seen these before; but the learning process never went further than this. The best experimental proof of the above statement is that, once the experiment had begun, there were no abrupt rises in the learning curve.

The physiological processes measured in connection with the work included metabolic rate, heart rate, and respiration. We were prevented from making additional measurements by the fear of encumbering the subject with too much apparatus, and thus hindering the freedom of his movements and his thoughts. Such a course must surely have impaired the validity of the results which we might obtain with the noise. Blood pressure, for example, and amplitude of the pulse beat, would no doubt have yielded interest-

ing results; but at the same time, their registration might have added a seriously disturbing factor. As it was, we were able to secure a very satisfactory adjustment to our apparatus on the part of our two subjects; and by the time we were ready to begin our experiments, neither of them reported any discomfort, nor even a consciousness of the set-up.

Metabolism was measured by the Haldane-Henderson-Bailey method (17). The subject, seated before a small table, had a gas mask strapped to his face, the harmonica rubber air-tubes passing over his right and left shoulders. These tubes were long enough so that he could lean forward over the table while working; and flexible enough to allow complete freedom of movement. Both had an internal diameter of one inch. The left-hand tube was connected with a length of pipe five inches in diameter, which led out of doors, and through which the subject received the fresh air that he breathed. The right-hand tube was connected with the Douglas bags (10) in which the exhaled air was collected, and with the apparatus for recording the breathing curves (to be described below). The passage of air through these tubes was controlled by means of Bailey valves (2).

The Douglas bags, each of which had a capacity of 100 liters, were attached to a rack immediately behind the subject. When one became filled, its mouth was closed by a valve, and the air was at the same time turned into another bag, without interrupting the experiment. An assistant detached the filled bag and carried it into the adjoining room where the volume of the air was measured, and samples taken for analysis.

The gas masks worn by the subjects during the early stages of the experiment were the Bailey mask (3), which resembles the type made for the United States Army. It covers the entire face of the subject, and has goggles for the eyes. The mask is strapped to the head; and part of its weight is supported by a cord, attached to the center of the mask, and running up to a horizontal rod above the head of the subject. In order to eliminate possible leaks along the border of the mask, a pair of ordinary rubber sponges, glued to a metal plate are strapped over the temples of the subject, one on each side, holding the mask close against the head. This is a much more cumbersome and less comfortable piece of apparatus than the Siebe-Gorman (7) mask, which was substituted for it.

This mask, which is made of rubber, is very small and light, being designed to cover only the mouth and nose of the subject.

Its general shape is triangular; like the other type, it is strapped to the head, but it is so light that it does not require additional support from above. A strip of flexible metal in the lining, and running along the border, allows the mask to be moulded to fit the general contour of the individual's face; and in addition, it is edged with a small pneumatic tube, inflated with an ordinary bicycle pump, thus holding the mask tightly against the face. It is a much more satisfactory piece of apparatus, in that it leaves the eyes of the subject entirely free to attend to the task in hand.

With the change in gas masks, we found a slight variation in some of our results, which, however interesting from the point of view of methodology, does not seriously affect the validity of our data, as we shall proceed to show. The table given below was compiled by averaging one subject's results for ten days preceding the change in masks, and comparing them with the figures obtained on corresponding days after the change. In each case the SD is given with the average, and the reliability of the differences is estimated by dividing a given difference by its SD. All of the following data were collected during 10-minute periods while the subject was at rest, and under quiet conditions.

TABLE 1

SHOWING DIFFERENCES IN MEASURES WITH BAILEY AND SIEBE-GORMAN MASKS

Measure	*Bailey Mask*		*Siebe-Gorman Mask*		*Diff.*	*D/SD$_d$*
	Av.	*SD*	*Av.*	*SD*		
Total ventilation liters	67.58	2.66	60.33	5.50	7.25	3.76
O_2 absorbed, %	3.15	0.22	3.70	0.23	0.55	5.50
CO_2 produced, %	2.49	0.11	2.92	0.11	0.43	11.00
Respiratory quotient	79.30	4.43	79.20	2.64	0.10	
Calories per square meter per hour	36.78	1.72	38.46	2.97	1.68	1.54
Breathing rate, cycles per min.	17.20	0.75	16.80	0.60	0.40	1.29
Breathing amplitude, mm.	2.12	0.32	2.45	0.26	0.33	2.54

The above table shows the total ventilation (the amount of air expired during the test) decreased on an average of 7.25 liters during the first ten days with the Siebe-Gorman mask. This in itself would tend to lower all of our other figures relating to metabolism, were it not for the fact that the lowered ventilation is counteracted almost perfectly by an increase in the percentages of oxygen absorbed and carbon dioxide produced. That these two processes varied proportionately is shown by the respiratory

quotient, or R.Q., remaining unchanged. As a result of the nice balance between lowered ventilation, and increased oxygen consumption, the metabolic rate (the calories liberated per square meter of body area per hour) remains the same. We are guided by two considerations: first, the obtained difference is not consistent enough to be reliable; and second, it would not be large enough to be significant, even though it were reliable. This is our most important measure of energy expediture, involving as it does all of the lesser functions, and being computed from them all; and any factor that affected the metabolic rate must seriously affect all of our results and interpretations.

We have included in our table the data on respiration, taken from the kymographic records. These show a slight decrease in the average breathing rate with the Siebe-Gorman mask, accompanied by a somewhat more significant increase in the amplitude of the breathing curves. (According to the data on reliability, the chances that a true difference exists between these measures, are 90 in 100 in the case of the breathing rate, and 99.4 in 100, in the case of the amplitude.)

We may suggest that with the Siebe-Gorman mask the breathing of our subject became more natural and somewhat less labored, due to the greater comfort of this mask. The slightly slower rate may not have been altogether compensated for by the increased depth of the breathing; which nevertheless might conceivably have resulted in the changing to a small extent of the composition of the exhaled air. This is not unnatural when the breathing is deepened a little; nor was the process carried far enough to upset the balance between the various functions.[3]

The above interpretation is little more than a guess, based on the general trend of the results. The study, was carried out with but a single subject. His introspective reports, would appear favorable in general to our hypothesis. Although he had considered himself adjusted fully to the Bailey mask, he nevertheless reported from the beginning that the new mask was more comfortable; and that the breathing seemed freer and more natural than before.

This discussion leads us into our next topic, respiration, and the method used in obtaining data on this process. A side tube of rubber, with a diameter of 7/8 in., connected the space between the

[3] For a good discussion of the various mechanical and other factors affecting determinations of basal metabolism, the reader is referred to Dubois: *Basal Metabolism in Health and Disease*, 1924 (11).

inlet and outlet valves of the gas mask with a large tambour, having a membrane 5 in. in diameter. A pointer attached to this tambour traced on the revolving drum of a kymograph the excursions of the membrane, caused by the subject's breathing. The balance between the resistance from the Douglas bag and the tambour was regulated by means of an adjutable clamp on the tube leading to the tambour. A brief discussion of this method, together with samples of the breathing curves obtained thereby, has been published by Rounds and Poffenberger (32). Not only does the method furnish data on breathing rate and amplitude; but the speech reactions, both implicit and overt, are clearly revealed in the curves which are obtained.

Heart beats were recorded kymographically on the same drum that was used for the breathing curves. The records were obtained by means of a cardiotachometer. This apparatus has been adequately described by Boas (6). Besides the records of the heart and the breathing, time was indicated by means of a chronograph, marking every 5 seconds. This completes our description of the measurements taken.

3. *Noises*

The sources of noise used in this experiment were two specially prepared 14-inch phonograph records, made by the Victor Company. One was made in a busy office room; and the other on an excessively noisy street corner in New York City (Herald Square, 35th Street, between Broadway and 6th Avenue). These records were used on a phonograph which was adapted for us by the E. E. Free Laboratories Inc., of New York. The machine was driven electrically, and was equipped with an electric pick-up, condenser, and amplifier, together with a radio loud-speaker for the reproduction of the sounds. Although it was possible to regulate the intensity of the noise, in our own experiment we always used the sounds at full blast, being interested primarily in studying the effects of noises of maximum intensity.

In our experiment, loudness ranged from 50 to 65 decibels (13, 26) in the case of the office sounds; and from 65 to 75 decibels in the case of the street sounds. When the former record was turned on, we heard, amid the general roar, the clicking of typewriter keys and adding machines, the hum of many voices and sounds which resembled the banging of boxes and other heavy articles. Among the various street noises, we could detect the blaring of countless automobile horns, policemen's whistles, the

occasional shouting of a human voice, the rattle and bang of trolley cars and elevated trains, and above all, the steady, deep-throated roar accompanying the heavy traffic of a large city.[4,5]

The noise did not remain at one constant level, but fluctuated throughout a given record. For this reason the *range* of loudness was given above, rather than the *average* loudness. In the present investigation, we made no efforts to correlate these variations in loudness with physiological changes in our subjects. When evaluated subjectively, the variations in loudness seemed less important and less disturbing than the general fact of the noise itself, which in this sense may be thought of as a constant condition.[6]

The room in which the experiment was conducted was an ordinary laboratory research room, 11 feet in width, by 24 feet in length, and 11 feet in height. It was neither soundproof nor unfurnished, was equipped with chairs, tables and cabinets for the various pieces of apparatus. When the noise was going on, it completely "filled" the room, drowning out all other sounds. Under the quiet conditions there was no disturbance beyond the low hum of the motor operating the kymograph, and the regular clicking of the cardiotachometer in the next room. These were constant conditions from the beginning of the research, and the subject adjusted himself to them, just as he was adjusted to the apparatus.[7]

4. *Subjects*

Two subjects served in the experiment, both males.[8] One was the writer himself; the other was also a graduate student in psychology. The latter was told that we were conducting a research on noise, and while he could scarcely help being aware of the measurements

[4] For data on the pitch ranges of such noises as these, see (26).

[5] The phonograph which produced the noises stood on a small table, about six feet from the subject, the loud-speaker facing in his direction. The machine was operated by the experimenter. Once started, the only attention it required was to have the needle set back at the beginning of the record, about once in every three minutes. One record was used constantly throughout a given series of experiments.

[6] An investigation dealing with the comparative effects of various kinds of noises and with the factor of unexpectedness, will shortly appear from the Columbia Laboratory (30).

[7] The research room was in the rear of the building. The window opened onto the grounds of the University, and it was largely shut off from the street by neighboring buildings. No one passed under the window at any time; and we worked at hours when the hallway outside our door was deserted. In this way we eliminated disturbances from this direction.

[8] Tests carried out in a sound-proof room showed no significant differences between the two subjects as regards auditory acuity.

taken, he was altogether unfamiliar with metabolic methods, and was told nothing whatever regarding the results until the end of the experiment. The writer kept himself in ignorance of the outcome of the study, in so far as possible, by working up the results only at intervals of two weeks, except towards the very end of the experiment, when it appeared that a level had been attained.

The nature of our work made it impossible to use many subjects. Besides the enormous tax upon the time of the technician, the capacity of the Haldane apparatus was limited. Owing to these considerations our plan was to use one subject as a check upon the other; and if any marked discrepancies should appear between the two sets of results, to introduce a third subject. This last step did not prove necessary.

5. *Procedure*

The experiments in which Subject H served, were performed daily, except Sundays, from 8:30 to 9:30 A. M.; those in which Subject E served, were performed from 11:30 to 12:30. The former came to the laboratory in the post-absorptive condition; *i.e.*, after a fast of from 12 to 14 hours; while the latter began his work about 4 hours after a light breakfast.

The general procedure was the same on all days for both the subjects. Immediately upon his arrival at the laboratory, the subject removed coat and collar, and reclined for 30 minutes upon a mattress. As he was alone in a quiet room, he generally slept through most of this period. He was then awakened, and the electrodes of the cardiotachometer were strapped to his chest. When he had taken his seat in a swivel chair before the work table, the gas mask was put over his face; following which came another rest period of ten minutes. During this period the subject settled himself comfortably in his chair, and rested with as little movement as possible. He was invited to sleep again if he could, and oftentimes he did fall into a light doze. The expired air was, of course, collected throughout this period and sample records of heart rate and breathing were taken, over two-minute periods. These furnished the resting data for the various measures.

At the end of this ten-minute rest period, the subject raised himself to a writing position, was given pencil and paper, and the problems to be added. At a given signal from the experimenter, he fell to work; and continued at top speed for the next twenty minutes. During the early stages of the research, the day's run

ended with this work period. Later, another rest period of 13 minutes was taken after the work, for the purpose of studying recovery effects. The conditions during this were the same as those for the initial 10-minute rest period.[9]

The actual data were collected in four experimental series, besides the adjustment series for each subject; and each of these will be described in detail.

To accustom our subjects to the apparatus, and chiefly to the gas mask, we allowed each one to sit with the mask on his face, for a few minutes daily during the first few days. After this we began taking records.

The adjustment of Subject H to the apparatus covered a period of 25 days, after the taking of records was begun. For the first five days, only the initial 10-minute rest period was given; but for the succeeding 20 days, the rest was followed by the full work period of 20 minutes. In this way we hoped to give the subject some practice in adding before beginning the experiments with noise.

During this period of adjustment, records of heart rate and breathing curves were obtained, and three bags of exhaled air were collected: one for the ten-minute rest period; one for the first 10 minutes of work; one for the last 10 minutes of work.

Our criterion of adjustment was that our subject should show a variation not exceeding 2 or 3 points on the average in his resting metabolic rate (calories per hour per square meter) from day to day.[10] As a practical and easy method of determining the progress of the adjustment process, we averaged the metabolic rates in groups of 5 days each, and calculated the SD for each group. When the curve for the averages and the SDs remained fairly constant over several consecutive groups, we considered that the subject was sufficiently adjusted to go ahead with the experiments.

Our experience with Subject H proved that it was not necessary to prolong the adjustment period. Subject E was less variable than H from the beginning; and by the end of the ninth day there was no need for carrying his preliminary training further.

[9] In deciding on the length of our work period, we were forced to choose between an intensive analysis of a comparatively short period, or a longer period which must perforce be treated more summarily—at least as regards analysis of metabolic rate. In view of the fact that we were stressing completeness in the treatment and presentation of results, we determined upon the former course; and, therefore, have adopted twenty minutes as the most convenient period with which to deal.

[10] This, of course, being determined from the data for the initial 10-minute rest period.

In collecting the adjustment data from E, we added a 3-minute recovery period at the end of the work. The other periods followed the schedule as outlined for H.

The experimental data were collected in four series which we will call A, B, C, and D. Subject H served in the first three series; Subject E in the fourth. The procedure in Series A was exactly the same as that described for the adjustment of Subject H, except that quiet and noisy days were alternated. On the latter days, the record of office noises was played at full intensity throughout the work period. This series lasted for 39 days, of which 20 were quiet and 19 noisy.

From the control days in Series A we learned that there were no consistent differences between the data for the two work periods of 10 minutes each. This fact suggested to us the idea of having both quiet and noisy conditions in one sitting. Besides eliminating

TABLE 2

SUMMARY OF EXPERIMENTAL SERIES

Ser.	*Sub.*	*Length*	*Rest*	*Wk. I*	*Wk. II*	*Wk. III*	*Rec. 1*	*Rec. 2*	*Conditions*
A	H	39 days	10 m.	10 m.	10 m.				Alt. quiet & noise days; off. noise
B	H	15 "	10 m.	10 m.	3 m.	7 m.	3 m.	10 m.	Wk. I—quiet; II & III—off. noise
C	H	4 "	10 m.	10 m.	3 m.	7 m.	3 m.	10 m.	Same as B—st. noise
D	E	19 "	10 m.	10 m.	3 m.	7 m.	3 m.	10 m.	Same as B—off. noise

the necessity for separate control days, this procedure would have the further advantage of enabling us to study the effects of a change from quiet to noisy conditions while the work was actually in progress; and as a consequence we devised the schedule which was followed in Series B and in all later series.

Series B was composed of a 10-minute rest period; a work period of 20 minutes; and a recovery period of 13 minutes. The record of office noises was begun at the beginning of the second 10 minutes of work, and was run continuously until the end of the work period each day. Heart rates and breathing records were taken as usual; and the exhaled air was collected in bags covering the following periods: the initial 10-minute rest period; the first ten minutes of work under quiet conditions; the first 3 minutes of work with noise;

the last 7 minutes of work with noise; the first 3 minutes of recovery; and the last 10 minutes of recovery. Series B was run for 15 days.

Series C was exactly the same as B, with the exception that the record of street noises was used. This series lasted 4 days, and shows the effect of changing the noise somewhat after the subject has shown evidence of adjustment to the first type.

Series D was like B, the only difference being that Subject E served in place of H. This series lasted 19 days.

Table 2 summarizes the salient facts regarding each of the four experimental series.

IV. Results

1. *Output of the Subjects*

Output in the present study is measured simply in terms of problems done during a given sitting. We may also extend our observations to cover the number of problems done correctly, comparing the data obtained under conditions of quiet with those obtained when the noises were present.

In Series A, the conditions were to be alternate quiet and noisy days, according to our original plan. Owing to occasional mishaps, it proved impossible always to follow this plan. As a result, we have the two sets of data somewhat out of alignment at several points. We have corrected this in presenting the results by setting each noisy day opposite the immediately preceding quiet day, and indicating breaks in the schedule by corresponding gaps in the tables.

The data on output, in Series A, are presented numerically in Table 3. From the table we see that there is a very slight improvement in speed throughout the series. This holds for both quiet and noisy days. The gain in accuracy is more marked. The subject is approaching his physiological limit; and there seems no reason for believing that the learning process itself will affect the validity of our comparison of the data for the two sets of conditions.

The effect of the noise upon output and accuracy varies considerably from one day to another. On the first noisy day the subject worked one more problem than he had done on the preceding quiet day; on the two following days his output remained the same for both quiet and noise. There is a great deal of overlapping between the two sets of results, throughout the series. At one point towards the end, the output during noise is as much as 8 points below that for quiet; while very shortly thereafter, it is 3 to 5 points higher for noise than for quiet. In other instances the differences are slighter.

What we have just said regarding number of problems worked is equally true in the case of accuracy. Here, however, it is true that for the first three noisy days the accuracy is lower than on the preceding quiet days; after that overlapping occurs at many points.

In order to ascertain what, if any, general tendencies might exist in these results, we have averaged our data in four groups each for quiet and noisy days. The composition of each of these eight

TABLE 3

PROBLEMS WORKED, NUMBER AND PERCENTAGES CORRECT ON QUIET AND NOISY DAYS IN SERIES A

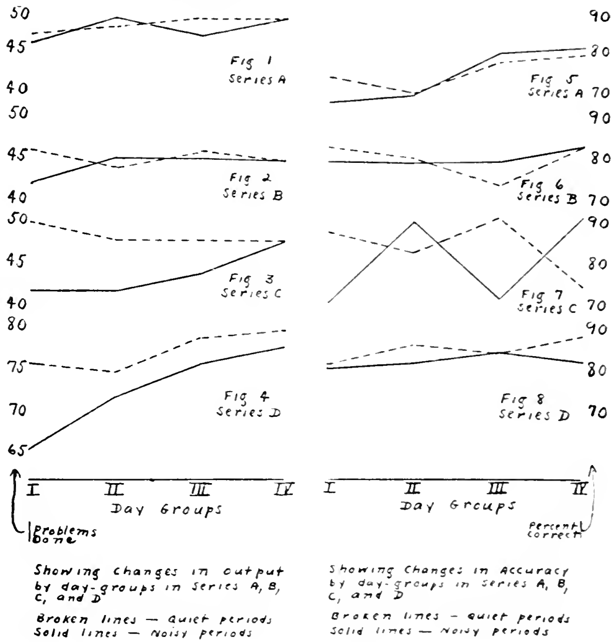
Quiet Days				*Noisy Days*			
Date	*Problems*	*No. Right*	%	*Date*	*Problems*	*No. Right*	%
1/13	45	34	75.5	1/15	46	29	63.0
1/16	45	35	77.8	1/17	45	34	75.5
1/19	48	36	75.0				
1/20	47	32	68.1				
1/21	50	38	76.1	1/22	46	31	67.4
Av.	47 ± 1.9	...	74.5 ± 3.3	Av.	46 ± 0.6	..	68.6 ± 5.3
1/23	50	33	66.0	1/24	48	35	72.9
1/26	45	30	66.7	1/27	49	34	69.4
1/28	47	34	72.4	1/29	47	36	76.6
1/30	48	36	75.0	1/31	50	32	64.0
2/2	50	37	74.1				
Av.	48 ± 1.9	......	70.9 ± 3.8	Av.	49 ± 1.0	...	70.7 ± 4.6
2/4	47	41	87.3	2/5	48	37	77.1
2/6	46	30	65.3	2/7	44	31	70.5
2/16	48	41	85.5	2/17	48	44	91.7
2/18	51	46	90.3	2/19	52	40	77.0
2/24	52	32	61.6	2/25	44	36	81.9
				2/26	47	39	83.0
Av.	49 ± 2.3	......	78.0 ± 11.7	Av.	47 ± 1.5		80.2 ± 6.5
2/27	49	38	77.6	2/28	48	40	83.4
3/4	48	39	81.4	3/5	53	45	85.0
3/6	49	37	75.5	3/7	52	43	82.7
3/9	48	39	81.2	3/10	46	40	87.0
3/11	50	42	84.0	3/13	45	32	71.1
Av.	49 ± 0.8	......	79.9 ± 3.0	Av.	49 ± 1.7	......	81.7 ± 5.6

groups is indicated in Table 3. As may be seen, the data for quiet days are broken up into four groups of five days each; while the grouping for the noisy days is determined by the preceding quiet days. The four groups under the head of noise are, therefore, less uniform in size than are the others: the first including but three days; the second, four; the third, six; and the fourth, five. The averages for these day-groups are also presented in Table 3.

The results by day-groups are given graphically in Figures 1 and 5. From the former we see that the overlapping of the two sets of results is still great: too great, indeed, for the obtained differences to have any significance, taken by themselves. The smallness of the groups prevents us from determining this fact by statistical methods; but we may say with certainty that any effect which the noises may have produced was slight. The results which we have presented are based upon the total number of problems done

during the entire twenty minutes of work; and from them we can tell nothing of the effect of the noise during the first minute, the second minute, etc., in this series.

The accuracy curves in Figure 5 are somewhat more conclusive than were the foregoing results. Here we observe a relatively low



Figs. 1–8

accuracy under the noise in Group 1. In this case, the difference in percentages of problems correct averages 7.1. In the three succeeding day-groups there is a progressive gain in accuracy with noise. In the second day-group, the two curves almost touch; while in the last two groups the accuracy averaged higher for noisy than for quiet days.

In the absence of other factors which might account for the above differences, it seems safe to attribute their occurrence to the effects of the noises. Thus we may say that the effect of the noise

was to produce a rather decided decrease in the accuracy of Subject H's work during the first three days or so. Thereafter, as the subject became adapted to the noise, the accuracy of his work was to a small extent increased on days when it was present. Although the differences themselves are slight, their trend is uniform throughout the remainder of the series; and on this account we may consider our results reliable.

We turn to the consideration of output in the other experimental series. Series B which followed immediately upon A, and lasted for 15 days, differed from it only in the manner of presentation of the noise. In this series, as in all thereafter, quiet days were eliminated, and both sets of conditions were presented during the one twenty-minute work period, the first half of which was quiet, and the second noisy. As stated before, the noises used were the same as those in Series A; namely, office noises.

TABLE 4

Problems Worked and Percentages Correct During Quiet and Noisy Halves of Sitting (Number of Problems Multiplied by 2)

Date	*Problems*		*% Correct*	
	Quiet	*Noise*	*Quiet*	*Noise*
3/25	40	38	90	74
3/26	46	44	87	73
3/27	46	42	91	76
3/28	50	46	64	96
Av.	46 ± 3.6	42 ± 3.0	83.0 ± 11.1	79.8 ± 9.5
3/30	44	44	70	68
3/31	44	46	70	83
4/1	46	48	92	92
4/2	44	42	91	76
Av.	44 ± 1.0	45 ± 2.5	80.8 ± 10.8	79.8 ± 9.0
4/6	42	46	81	87
4/7	46	44	70	59
4/8	48	46	75	83
4/9	48	44	71	91
Av.	46 ± 2.5	45 ± 1.4	74.3 ± 4.3	80.0 ± 12.6
4/15	42	42	81	86
4/16	44	44	73	68
4/17	50	48	96	96
Av.	45 ± 3.5	45 ± 1.9	83.3 ± 9.5	83.3 ± 10.5

Table 4 gives the output and accuracy data for each day in Series B as well as the averages in four day-groups. Since the figures cover two periods of ten minutes each, the number of prob-

lems worked in each period, noisy and quiet, is approximately half the corresponding number for Series A. In order to render our results comparable, we have, therefore, multiplied by 2 the number of problems worked during each half of the sitting.

The data in Table 4 show that for the first four days the number of problems worked was consistently lower during the second ten minutes (the noisy period) than during the first ten minutes (the quiet period). Before attributing this difference in output to the effect of the noise, we must first consider briefly several other possibilities which might account for it.

The question of "warming up" is at once eliminated, for the simple reason that the differences during the first four days are exactly opposite in direction to those which might be expected were this a case of "warming up." As a matter of fact, if "warming up" did occur, and it is easily possible that it might, since no preliminary work period was given, it was considerably overbalanced by some other factor which was operative during the second ten minutes of work.

The possibility of fatigue[11] towards the end of the period seems no more promising as an explanation. In the first place, twenty minutes would be too short a time for fatigue to manifest itself in the subject's work, and particularly in work as light as this[12]; nor did the introspections of the subject himself reveal any evidence of it. By the time Series B was run, the subject had had considerable practice in the kind of mental work he was doing. This being true, we should expect fatigue, if present, to keep the output during the second ten minutes consistently below that for the first ten minutes throughout the entire series. Such, however, is obviously not the case. Beginning with the fifth day, the two sets of results for noise and quiet overlap in much the same manner as described in Series A; the output being greater, sometimes with the noise, sometimes with the quiet conditions. This leads us to attribute the difference once more to the effect of the noise.

The discussion which we have just concluded might be applied equally well to our data on accuracy in Series B. The picture there is much the same: a relatively low accuracy for the first three days under noise; after which the results continually overlap.

11 The word fatigue, as used here, is simply a convenient term for denoting those progressive decreases in output which occur when any kind of work is protracted over a long enough period of time. For a critical discussion of this concept, see Schubert (33).

12 See Poffenberger (27, 28, 29), and Thorndike (37).

These data are presented graphically in Figures 2 and 6. From them it is evident that, as in Series A, output is affected very little by the noise, excepting in the first group. It is true, however, that in this series there is a somewhat greater tendency for output, during the noise, to remain below output during quiet conditions; but the differences remain small at all times.

The curves for accuracy are in many respects suggestive of those in A. In the first two groups the noise seems to have had an adverse effect upon the accuracy of the work; but the accuracy for noisy work, after remaining almost constant at approximately 80 percent during the first three day-groups, rises in Group IV to 83.3 percent —exactly the same as the corresponding figure for quiet.

We must now raise the question as to the reason for the results in Series B repeating so closely those in A. We have seen that the subject had apparently adjusted himself to the presence of the noise throughout the entire twenty minutes of work, and had learned to work as well, if not better, than when this noise was not present. Then, the experimental set-up being changed slightly, the entire process of adjustment must be gone over once more. Two possible answers to our question suggest themselves.

The first is that, by fractionating the data to this extent, we have come upon an immediate noise effect which was present in Series A, but which was swallowed up in the more general effect observed by regarding the entire twenty minutes in one. Conceivably the initial effect of the noise was to retard; a tendency which the subject gradually overcame as the sitting progressed. Moreover, adjustment to this initial effect might very well require a longer time than adjustment to the general presence of the noise. If this hypothesis be true, we should say that in Series A we were observing the adjustment of our subject to the general effects of the noise over a longer period of time; while in B we observed the later stages of adjustment to the more immediate initial effects. Possibly, had we gone further and cut our noise period to five minutes, we might have obtained a third set of curves, resembling in their general form those in A and B.

A second possible answer to our question might be found in the "set" of the subject. In Series A noise and work began simultaneously; and the subject fell into the swing of his task to the accompaniment of the noise. In B he was already well under way with his work when the sound was introduced; and during the second half of the work period he was faced with the necessity of keep-

ing this work up to standard, while, at the same time, adjusting himself to the presence of the other stimulus. Such an adjustment might well result in a temporary loss in quantity and quality of work done.

These data do not permit us to carry through the analysis to the solution of the problem. In our other data—in heart rate, respiration, and metabolism—we have come closer to accomplishing this result; and we may, therefore, hope to throw additional light upon the question later.

Series C was very brief, lasting only four days. The procedure here was the same as in Series B. We wished merely to discover what effect would be produced by a change in the noises used; and to this end we experimented with the record of street noises. This record, it will be remembered, was somewhat louder than the other one.

The data on output and accuracy in Series C are presented in Table 5, and in Figures 3 and 7. Interestingly enough, in this

TABLE 5

PROBLEMS WORKED AND PERCENTAGES CORRECT DURING QUIET AND NOISY CONDITIONS (NUMBER OF PROBLEMS MULTIPLIED BY 2)

Date	*Problems*		*% Correct*	
	Quiet	*Noise*	*Quiet*	*Noise*
4/20	50	42	88.0	71.5
4/21	48	42	83.4	90.5
4/22	48	44	91.6	72.8
4/23	48	48	75.0	91.7

series it is the results in output which are the most clear-cut and decisive. The curve of adjustment is almost perfect, and in not one case is there crossing of the two lines. The effect of noise upon output is here unmistakably in the direction of retardation; an effect which becomes progressively less marked from day to day, until it disappears altogether at the end of the series.

Our data on accuracy in this series are not at all conclusive. This may be due in part to the fact that we have not sufficient results to present averages as heretofore. Certainly we would not be justified in attributing the changes which we observe here to the effect of the noise, in view of the wide fluctuations that previous experience has led us to expect in accuracy. We can only present the data as they stand, and leave them without further comment.

In Series D the new subject served. In all other respects this series, which lasted 19 days, was similar to B. The record of office noises was used in this series.

Table 6 presents the usual data on output and accuracy for Series D, the curves for which are given in Figures 4 and 8. It is

TABLE 6

PROBLEMS WORKED AND PERCENTAGES CORRECT UNDER QUIET AND NOISY CONDITIONS IN SERIES D (NUMBER OF PROBLEMS MULTIPLIED BY 2)

Date	Problems		% Correct	
	Quiet	*Noise*	*Quiet*	*Noise*
5/11	90	48	73	83
5/12	74	70	89	69
5/13	74	70	84	89
5/14	72	74	81	76
5/18	70	66	83	88
Av.	76 ± 7.3	66 ± 9.2	82.0 ± 5.2	81.0 ± 7.6
5/19	76	74	82	76
5/20	76	74	87	92
5/21	72	70	94	91
5/22	70	70	86	77
5/23	80	72	85	75
Av.	75 ± 3.6	72 ± 1.7	86.8 ± 4.0	82.2 ± 7.7
5/25	74	72	81	83
5/26	82	78	93	90
5/27	98	78	78	74
6/4	68	74	...	
6/5	72	76	86	92
Av.	79 ± 10.6	76 ± 2.4	84.5 ± 6.3	84.8 ± 7.0
6/6	76	72	90	86
6/8	82	76	93	87
6/9	80	82	83	83
6/10	80	82	88	73
Av.	80 ± 2.2	78 ± 3.7	88.5 ± 3.8	82.3 ± 5.5

evident that Subject E was a much more rapid worker than was H. As in the two preceding series, however, we have multiplied the number of problems worked in each ten minute period by 2, in order to facilitate the comparison of the results from each series.

In this series, as in C, the day to day results are much less equivocal in output than in accuracy. The effect of the noise on the first day was striking and unmistakable, cutting down the output by almost one-half. During the succeeding days, it is possible to trace the process of adjustment. This adjustment came slowly, probably because this was the subject's first experience with the

noise. The slightly higher output during noise on the fourth day was very likely due to chance, and does not occur again until the fourteenth day. From then on, noisy and quiet days overlap until the end of the series. The peculiar results on the fourteenth day (6/4) are probably due to loss of practice during the week's break just preceding, and to the regaining of form during the day's work.

The data on accuracy in this series are interesting. At first glance, their trend might seem to differ very little if at all, from those in Series A, B, and C. There is the characteristic overlapping of the results which we have been led to expect. Closer examination, however, will reveal the fact that this overlapping occurs less frequently after about the middle of the series; or, in other words, the effect of the noise upon accuracy is more clear-cut towards the end than at the beginning.

The curves of averages (Figure 8) show, after the first five days, a parallel increase in output in the two periods, the noisy, however, remaining almost constantly below the quiet. The accuracy curve is altogether different from any that we have so far observed. The noise in this series seems to have held the accuracy down, while accuracy during quiet conditions increased from 82.0 to 88.5 per-cent.

These differences in the effect of noise on the accuracy of Subjects H and E may have resulted from several factors, such as differences in speed of work as well as possible differences in drive.

To summarize our findings thus far, we may say that the noises which we used produced a definite effect upon the work of both subjects; an effect which showed itself either in output or in accuracy, or in both. The changes produced by the noises were generally slight, and tended to be obscured by the day-to-day variability of the results. Moreover, there was found considerable overlapping of the two sets of results, for noisy and quiet periods. Nevertheless, changes appeared, always in the direction of retardation at first; and it was possible to trace the course of the adjustment of our subjects to the noise.

This adjustment process took two shapes. In the case of output, it consisted of a gradual increase in the number of problems worked during the second or noisy period, until the averages of the results in small groups of four or five days each showed no appreciable difference between output in the two periods. Overlapping of the two curves, or the striking of a parallel course over several such day-groups was taken as a criterion of adjustment.

In the matter of accuracy, adjustment seemed to take the form of an increase under noisy conditions with Subject H. This occurred in two of the series, while in the third, no consistent changes at all were observed. Subject E failed to show any adjustment in accuracy, his percentage of problems done correctly remaining approximately the same under the noisy conditions.

The time required for adjustment to the noise was found to range roughly from five to ten days, according to whether the subject had served in previous series or not. Changes, either in the noises themselves, or in the matter of presentation, resulted in a repetition of the adjustment process, though in a much abbreviated form. To this extent, at least, we found evidence of transfer in our experiments.

In view of all that we have had to say regarding the variability of our results, one might well raise the question as to the effects of the noise upon the general variability in performance of our subjects. Although the number of cases within each of our day-groups is small—too small, probably, to be highly reliable, we may attempt to answer the question in part, by calculating the standard deviations and the coefficients of variability for each of these groups.[13]

These SDs will be found in the respective tables for Series A, B, and D. Series C, it will be remembered, consisted of but four days, and therefore it was impossible to present averages in this instance. The coefficients of variability are given in Table 7.

The general trend of the results indicates that the effect of the noise was first to decrease, then gradually to increase the variability of output. This is most clearly shown in Series A and B. In the latter, the overlapping in the second day-group may or may not be an exception to this statement. In the case of Series D, there is first an increase in variability during the noisy period; then a sharp drop, followed by a gradual gain, until the end, where variability under noise again slightly exceeds variability under quiet. With the exception of the first day-group, Series D resembles Series A in this respect more closely than it resembles Series B. This, moreover, that what we would naturally be led to expect, since both A and D mark the subjects' first experience with the noise; while B is rather an intermediate series, whatever may be our interpretation of it.

[13] Coefficient of variability, or $V = \frac{SD \times 100}{Av.}$.

TABLE 7

Showing Coefficients of Variability in Output and Accuracy for Quiet and Noisy Periods in Series A, B, and D

Day-Group	*Output*		*Accuracy*		*Series*
	Quiet	*Noise*	*Quiet*	*Noise*	
I	4.04	1.30	4.43	7.86	
II	3.96	2.04	5.36	7.89	A
III	4.69	3.19	11.80	9.03	
IV	1.63	3.47	5.40	6.85	
I	7.83	7.14	13.44	11.71	
II	2.27	5.43	13.02	11.50	B
III	5.43	3.18	5.81	16.10	
IV	7.61	4.32	11.50	12.18	
I	9.60	12.94	6.37	9.28	
II	4.86	2.36	4.63	9.23	D
III	13.59	3.16	7.23	8.31	
IV	2.75	4.74	4.35	6.72	

Turning to accuracy, we again find a closer agreement between Series A and D than between either of these and Series B. Taking the two former together, we may say that the noise tended in both to increase the variability of accuracy at first; the two sets of results, however, drawing closer together towards the end of each series. Even at the very end, variability was higher during the noisy period than during the quiet period. In Series B, exactly the opposite was true: the noise at first decreased the variability of the subject's accuracy, increasing it slightly towards the end of the series. Here again we have B as an intermediate step between A and D. It is regrettable that Series C was too short to permit similar calculations as to variability.

Were we obliged to generalize from our data on mental work alone, we might well conclude that noise, or a certain kind of noise at least, has little or no real effect upon either output or accuracy. The important question at issue, however, is whether the differences between quiet and noisy periods do not become more significant when energy expenditure during the work as well as output is taken into consideration. This question we shall essay to answer in the pages which follow.

2. *Energy Expenditure during the Work*

Metabolism is, of course, the measure of the energy expenditure of our subjects. We shall take as our chief index of this process

metabolic rate, which we have already defined as the number of calories produced per hour per square meter of body surface. In this section we shall follow the same style of presentation as in the data for output and accuracy, giving the day-to-day results, as well as the averages for small day-groups.

In Series A we have determined the metabolic rate for the ten-minute rest period (Rest); the first ten minutes of work (Work I) and the second ten minutes of work (Work II). The *work curve* is plotted by laying out the successive work periods along a horizontal axis; and the metabolic rates along vertical axes; and drawing lines between the points which have been located thereon.

In Table 8 are given the metabolic rates for Rest, Work I, and Work II in Series A. We see that for the first seventeen days of

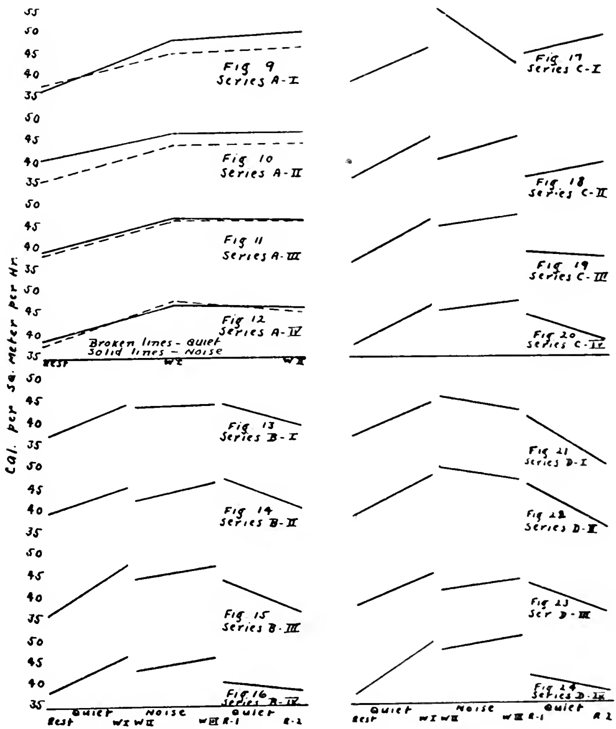
TABLE 8

Showing Changes in Metabolic Rates with Work for Quiet and Noisy Days in Series A

Date	*Quiet Days*			*Date*	*Noisy Days*		
	Rest	*Work I*	*Work II*		*Rest*	*Work I*	*Work II*
1/13	39.05	45.40	49.25	1/15	37.45	46.82	54.06
1/16	35.29	40.16	46.09	1/17	32.30	46.82	46.59
1/19	38.70	45.56	41.39				
1/20	36.57	48.13	47.47				
1/21	38.77	45.83	49.97	1/22	39.24	50.57	49.37
Av.	37.68	45.02	46.83	Av.	36.33	48.07	50.01
1/23	36.58	48.65	47.78	1/24	43.99	46.91	47.62
1/26	36.03	44.20	43.33	1/27	37.47	47.30	52.04
1/28	35.68	43.36	40.27	1/29	39.29	44.23	43.94
1/30	33.36	40.41	46.28	1/31	41.37	48.73	43.92
2/2	37.80	43.24	45.21				
Av.	35.89	43.97	44.57	Av.	40.53	46.79	46.88
2/4	35.00	53.43	45.29	2/5	40.92	46.08	45.09
2/6	38.86	44.07	49.28	2/7	39.26	47.77	47.17
2/16	37.45	43.36	43.63	2/17	39.42	50.21	52.46
2/18	38.62	46.83	47.59	2/19	41.79	47.96	47.36
2/24	44.61	45.32	45.49	2/25	36.18	44.55	43.66
				2/26	41.50	45.48	41.93
Av.	38.91	46.60	46.25	Av.	39.68	47.01	46.28
2/27	37.15	47.53	47.84	2/28	36.73	46.46	45.57
3/4	40.20	46.75	41.72	3/5	38.49	48.46	49.35
3/6	37.26	46.53	46.09	3/7	36.58	45.82	47.96
3/9	33.84	50.52	44.11	3/10	39.36	48.36	44.11
3/11	41.55	49.05	46.66	3/13	43.70	46.36	44.64
Av.	38.00	48.08	45.28	Av.	38.97	47.09	46.33

this series, the working metabolism of Subject H is consistently higher on any given noisy day than on the corresponding quiet day.

Although there are quiet days during which the working metabolic rate is higher than on certain noisy days, the two sets of data never overlap at corresponding points in the first half of the series. The differences between the two range from less than one to more than five points. During the last half of the series, however, we observe the rates beginning to overlap, just as did the output data in the preceding section; and this we took to indicate adjustment to the noise on the part of the subject. Having observed this much, we are now ready to discuss the averages of day-groups. These will be found in Table 8 and in Figures 9–12.



FIGS. 9–24

Showing Changes in Metabolic Rate in Successive Work Periods by Day-Groups in Series A, B, C, D.

We have already described our method of plotting a work curve. In Figures 9–12 are shown four such work curves—one for each of the four day-groups in Series A. Each of these, therefore, represents a composite picture of the changes in metabolic rates during the days covered by that group. All show in a very striking manner the effect of the noise upon the working metabolism of the subject, and the progress of his adjustment to this noise. From the figures we see that, in all four day-groups, the noise is about equally effective in each work period; that is to say, there are no striking differences between Work I and Work II in regard to the effect of noise on metabolic rate.

In the second day-group (Table 8 and Figure 10) we note that the average resting metabolism is almost 5 points higher for noisy than for quiet days. The table shows high resting metabolic rates on three out of the four noisy days in this group. The most obvious explanation for this tendency, which is present to a lesser extent in other day-groups of this series, might lie in the emotional response of the subject to the expectation of the noise. Subject H knew on what days the noise was to be present; and this fore-knowledge might well have affected his emotional tone sufficiently to have raised his resting metabolism.

In Series B (Table 9) we have samples of the metabolism of our subject during the following periods: Rest (10 minutes); the first ten minutes of work (Work I); the first three minutes of the second work period (Work II); the last seven minutes of the second work period (Work III); the first three minutes of rest following the work (Recovery 1); and the next ten minutes of recovery (Recovery 2). Work I was performed under conditions of quiet; Work II and Work III under the noisy conditions.

The day-to-day data on metabolism in this series are less conclusive than were the corresponding measures of output and accuracy. Judging by our criterion of overlapping of the results, the process of adjustment to the noise, which we traced in Series A, is comparatively undisturbed by the new procedure in this series—at least when we measure the effects of the noise in terms of metabolic rate. Even on the first day, the metabolic rates for both noisy periods are slightly below those for the quiet period. Work II, moreover, which was introduced in the hope of discovering any initial effects of the noise during the first three minutes of its presentation, is wholly negative; for it remains consistently lower than Work III throughout the series. Evidently, then, the effect of the noise upon

TABLE 9
METABOLIC RATES FOR SUCCESSIVE DAYS IN SERIES B

Date	Quiet Rest	Quiet Work I	Noise Work II	Noise Work III	Quiet Rec. 1	Quiet Rec. 2
3/25	34.96	46.58	41.65	44.34	43.45	
3/26	38.14	46.11	42.61	40.01	41.09	40.70
3/27	36.70	42.16	43.61	45.16	45.75	38.24
3/28	39.92	42.14	47.53	47.93	46.97	40.54
Av.	37.43	44.25	43.85	44.36	44.32	39.83
3/30	32.65	46.15	43.69	46.30	45.46	38.68
3/31	42.79	40.23	37.71	42.18	45.96	37.84
4/1	41.79	41.02	44.72	43.92	45.71	38.80
4/2	41.77	54.04	42.80	54.11	52.36	45.28
Av.	39.75	45.36	42.23	46.63	47.37	40.15
4/6	38.52	49.81	49.06	49.40	46.10	34.51
4/7	35.55	45.56	41.35	46.12	41.72	35.62
4/8	33.87	45.58	42.82	45.38	43.27	37.41
4/9	36.36	50.32	45.00	47.36	44.82	38.46
Av.	36.03	47.82	44.56	47.07	43.98	36.50
4/15	38.31	46.98	43.44	44.05	40.44	37.19
4/16	37.99	46.03	44.19	46.34	41.66	39.45
4/17	38.45	47.68	42.40	47.75	39.63	38.59
Av.	38.25	46.90	43.34	46.05	40.58	38.41

metabolism is one of summation, after the subject has become partially adjusted.

One cannot fail to note the rather curious effect which occurs on the sixth day of this series (3/31). The rates for all three work periods, while retaining their relative positions with respect to one another, drop below the rtae for resting metabolism. This effect seems to be the product of a rather high resting metabolism for that day, together with working metabolic rates which are somewhat lower than ordinary. Inasmuch as we are here concerned primarily with the relationships existing between the three rates for work, this seeming anomaly need not concern us further now. When we come to discuss the increases in metabolic rate accompanying mental work, we shall consider this particular case at greater length.

When the data from this series are averaged in day-groups and the curves plotted (Figures 13–16), they show us that there is very little change in the adjustment process throughout the entire series. In the first two groups, Work III is very slightly above Work I in metabolic rate; while in the last two groups, it is just below Work I.

The relationship between Work II and Work III, the two noisy periods, remains almost constant, with the latter consistently above the former.

Recovery shows the greatest amount of change in Series B. During the first two day-groups, it will be noted, the average metabolic rate for the first three minutes of rest after the cessation of work and noise (Rec. 1) was as high, if not higher than the working metabolic rate. Beginning with the third day-group, the rate for Rec. 1 falls considerably below that for Work III; until, in the fourth day-group, it is only slightly above the rate for Rest, as determined at the beginning of the sitting. Recovery 2, on the other hand, closely approximates the resting rate, showing very little change throughout the series.

It is regrettable that we have no control data on recovery after mental work under quiet conditions. We can only hope that the combined data from Series B, C, and D will in some measure make up for this deficiency. In view of the very evident adjustment which progresses uniformly through Series B, however, we shall venture to attribute the changes in Rec. 1 to further adjustment to the noise on the part of the subject.

There is one other question which arises in connection with the comparison of the working metabolic rates under quiet and noisy conditions. Supposing that we average together the metabolic rates for Work II and Work III, so as to obtain a general picture of the working metabolic rate under the noisy conditions; how will this compare with the picture for Work I performed under quiet conditions? If we average them, however, are we to give equal weight to Work II and Work III or not? Should we not give a double weight to the latter, since it is approximately twice as long as the former; and since one ordinarily expects measures of average rate to be more accurate, the longer the period over which they are observed? On the other hand, should we desire to give due representation to any possible immediate noise effects which might show themselves in the first (and, incidentally, the shorter) work period, we would naturally expect to assign the double weight to it, rather than to the second period.

Without attempting to decide between these alternatives, we have averaged the metabolic rates for Work II and Work III in ratios 1 : 2; 1 : 1; and 2 : 1; and presented the data for all three in Table 10. From this table, we see that in each case the metabolic

TABLE 10

SHOWING METABOLIC RATES FOR WORK I, AND FOR WORK II AND WORK III, AVERAGED IN THREE DIFFERENT RATIOS, FOR SUCCESSIVE DAY-GROUPS IN SERIES B

Group	*Work I*	*Work II & III*		
		1 : 2	*1 : 1*	*2 : 1*
I	44.25	44.19	44.11	44.02
II	45.36	45.16	44.43	43.70
III	47.82	46.23	45.87	45.40
IV	46.90	45.15	44.70	44.24

rate for the noisy period is consistently below that for the corresponding quiet period; the only difference being in the amount of difference between the two. When greater weight is given to the second and longer of the noisy periods, the values are almost identical; when greater weight is given to the shorter period, this brings the value for noise several points below that for quiet. Averaging the two in equal ratios results in values for noise which fall approximately midway between the other two. We are inclined to the belief that the first method of averaging, namely by giving greater weight to the longer period, is the proper procedure.

The metabolic data for the four days in Series C are given in Table 11, and in Figures 17–20. In this series the change in the

TABLE 11

SHOWING METABOLIC RATES FOR SUCCESSIVE DAYS IN SERIES C

Date	*Quiet*	*Quiet*	*Noise*	*Noise*	*Quiet*	*Quiet*
	Rest	*Work I*	*Work II*	*Work III*	*Rec. 1*	*Rec. 2*
4/20	38.16	46.03	55.03	42.36	44.65	48.52
4/21	36.08	45.92	40.68	45.49	36.04	39.61
4/22	36.80	46.43	45.01	47.30	38.90	37.86
4/23	37.82	46.74	45.70	47.74	44.57	38.50

noise used resulted in a marked change in the form and relationship of the metabolic rate curves. On the first day the rate during the first three minutes of work with noise was 9 points above that for the ten minutes of quiet work; while for the last seven minutes of noise, the rate was almost 4 points below that for quiet. This means that there was a difference amounting to almost 14 points between the metabolic rates for the two noisy periods, the second one being considerably lower. On each of the three succeeding days, however, the first three minutes of noise showed a lower

metabolic rate than did the last seven minutes; and on the last two days the rate for the ten minutes of quiet work fell midway between the rates for the two noisy periods.

The introduction of the new noise presented a new condition, to which the subject was obliged to adjust himself. This adjustment, however, evidently came more rapidly than did the adjustment to the first set of noises; undoubtedly because of the subject's previous experience with those noises.

The fact that, at the beginning of the series, the first three minutes of noise showed the greatest effect, is interesting. Generalizing from the four pictures of the work curve in Figures 17–20, we may say that the immediate effects tend to show up most strongly at the beginning of the series. Adjustment, likewise, appears first in this phase; and during the latter stage of the series, the noise becomes cumulative rather than immediate in its effect. As to the sharp decline in metabolic rate during Work III on the first day, this possibly was due to the sudden large burst of energy which was expended during Work II; and after which the subject slacked up somewhat in his effort. This, however, must remain a conjecture, for we have no fractionated record of output with which to compare our data on metabolism.

Our data on recovery in this series also show interesting changes. On the first day, the metabolic rates for both recovery periods are higher than the rate for Work III, and Recovery 2 is higher than Recovery 1; while thereafter the two gradually assume a normal relationship to one another. The data for the fourth day bear an almost perfect resemblance to the corresponding data in the preceding series, though Work III is just a bit higher than Work I. We may say that by the end of the fourth day this subject gives evidence of well nigh perfect adjustment to the new noise, as far as his energy expenditure goes.

We now come once again to the problem of weighting in constructing an average score which shall fairly represent the metabolic rates of Work II and Work III. In Series B, we saw that by giving the greater weight to the longer work period, we automatically gave the greater weight to the period showing the more marked noise effects. Other considerations, moreover, confirmed our belief that we were following the correct procedure there. Now, however, we are faced with a slightly different question. Do we wish to continue giving the greater weight to that period which shows the larger noise effect? If so, we will be obliged to give the larger weight to

Work II on the first day, and to Work III on the three remaining days. On the other hand, if we wish to be consistent, we should give the larger weight to the longer period, Work III, on all four days.

In computing a metabolic rate for the total noisy working time, we have continued here, as elsewhere, to assign the double weight to Work III in averaging; and the data thus obtained are presented in Table 12. The results for quiet and noisy work are very nearly

TABLE 12
SHOWING METABOLIC RATES FOR WORK I AND AVERAGES FOR WORK II AND WORK III IN SERIES C

Date	*Work I*	*Work II & III*	*Ratio*
4/20	46.03	44.94	1:2
4/21	45.92	43.89	1:2
4/22	46.43	46.54	1:2
4/23	46.74	47.06	1:2

alike, with noise somewhat the lower of the two excepting on the last day.

We come next to Series D, the data for which will be found in Table 13, and Figures 20–24. From the day-to-day results, we see that the noise produced a definite and fairly well-marked effect for the first three days; but that thereafter the metabolic rates begin to overlap during quiet and noisy periods. We note, however, that for at least the first half of the series the rate for Work II remains higher than that for Work III; while during the latter half, this relationship is reversed. This, of course, is in line with our conclusions regarding the change in nature of noise effects with adjustment on the part of the subject.

When studied by day-groups, these results are in close agreement with those from Series C. As in that series, the effect of the noise shows up most strongly in Work II at the beginning, and in Work III at the end of the series. The adjustment process required slightly longer here than in C, however; no doubt because the subject had no previous experience with the noise. One other point worthy of note in the present series is the fact that the two recovery periods seem "normal," *i.e.*, the metabolic rate during Recovery 1 is but slightly below that for Work III, while Recovery 2 closely approximates the resting rate and in some cases even tends to fall slightly below it. There is very little evidence for the carrying over of noise effects into the recovery periods, or for adjustment therein.

TABLE 13

SHOWING METABOLIC RATES FOR SUCCESSIVE DAYS IN SERIES D

Date	Quiet Rest	Quiet Work I	Noise Work II	Noise Work III	Quiet Rec. 1	Quiet Rec. 2
5/11	36.63	41.14	47.34	42.13	35.52	35.67
5/12	36.23	39.53	44.18	40.73	40.37	35.80
5/13	34.53	42.89	46.18	42.49	43.88	35.32
5/14	39.97	47.37	46.34	48.52	43.31	37.46
5/18	36.96	52.33	45.61	38.16	41.76	30.36
Av.	36.86	44.65	45.93	42.41	40.97	34.92
5/19	39.97	49.48	48.58	47.48	39.67	36.92
5/20	39.16	49.28	44.30	44.06	43.93	35.78
5/21	37.11	44.65	52.87	41.90	49.69	34.23
5/22	39.89	52.79	44.00	48.00	47.01	34.44
5/23	35.62	41.04	56.74	49.38	......	......
Av.	38.35	47.45	49.30	46.16	45.08	35.34
5/25	38.50	43.63	43.21	41.35	45.23	36.81
5/26	44.31	50.01	45.75	48.69	48.25	39.39
5/27	36.42	44.27	39.31	43.99	37.73	35.58
6/4	32.96	43.73	39.25	40.97	43.30	34.32
6/5	35.47	43.10	38.14	43.42	36.52	33.56
Av.	37.53	44.95	41.13	43.68	42.21	35.93
6/6	34.61	40.95	43.08	41.06	38.74	34.83
6/8	39.56	44.37	43.60	47.24	42.75	37.73
6/9	42.66	50.82	49.96	51.61	43.75	41.31
6/10	32.98	42.83	35.11	43.36	39.36	35.51
Av.	37.45	44.74	42.94	45.82	41.15	37.35

In constructing an average for Work II and Work III, we have followed in this series the same principles that we laid down in Series C, assigning the double weight to Work III throughout. These data are presented in Table 14.

TABLE 14

SHOWING METABOLIC RATES FOR WORK I AND AVERAGES FOR WORK II AND WORK III IN SUCCESSIVE DAY-GROUPS OF SERIES D

Group	Work I	Work II & III	Ratio
I	44.65	43.58	1: 2
II	47.45	47.21	1: 2
III	44.95	42.83	1: 2
IV	44.74	44.86	1: 2

As in Series C, this method of treatment masks the effects of the noise in the present series. In the first day-group, the increase in metabolic rate during Work II is not sufficient to overcome the drop which occurs during Work III; and, consequently, the aver-

age rate for the two noisy periods is slightly below that for the quiet period. The difference, however, is too slight to be significant. In the second day-group the same thing is true. In the third group the drop is more apparent; while in the last the two sets of results draw so close together as almost to touch; and this we take as fairly good evidence of adjustment on the part of our subject, especially since the differences in the other three groups were so very small.

Let us next turn our attention to the changes in variability of metabolic rate, measured in terms of the coefficients of variability of the scores within the several day-groups of Series A, B, and D. These data are presented in Table 15. We may summarize our

TABLE 15

Showing Coefficients of Variability of Metabolic Rates Within Successive Day-Groups of Series A, B, and D

	Group	*Rest*	*Work I*	*Work II*	*Work III*	*Rest*	*Work I*	*Work II*
	I	3.93	5.83	6.49		8.10	3.68	6.16
	II	4.04	6.07	5.80		6.00	3.48	7.13
A	III	8.15	7.75	4.25		4.84	4.06	7.24
	IV	7.06	3.14	4.75		6.64	4.56	4.34
	I	4.90	4.74	5.11	6.40			
	II	10.35	12.12	6.41	9.78			
B	III	4.70	4.70	6.53	3.23			
	IV	0.50	1.45	1.69	3.30			
	I	4.72	10.38	2.25	8.07			
	II	4.45	8.66	10.00	5.97			
D	III	10.21	5.68	7.01	6.30			
	IV	10.28	8.28	12.50	8.76			

findings from all three series as follows: when the mental work was carried on under quiet conditions, there was a tendency for metabolic rate to increase in variability; and to decrease slightly during the later day-groups. When noise is added to the situation, these trends are exactly reversed. Series A and D are in substantial agreement on this point; while the results from B are inconclusive. The noise effects, however, tend to diminish as the series progresses.

By way of summing up all our metabolic findings thus far from the four experimental series, we may say that in every case the noise produced a definite effect upon the metabolic rates of our subjects. This effect changes its aspect, as the process of adjustment to the noise goes forward. In the early stages of any given series, the noise effect is immediate, appearing as soon as the noise is applied

and disappearing as the noise continues. As the series progresses, however, the noise effect tends to appear more markedly in the later work period, and to disappear from the earlier periods. The effect, in the direction of an increase in the working metabolic rate, sometimes amounts to as much as 9 calories per hour, per square meter of body surface.

When the data from the two noisy work periods are averaged and compared with the corresponding quiet work periods, however, the effect of the noises is almost wholly concealed; a fact which tends to minimize the significance of the changes produced by noise in the metabolic rate. Furthermore, we are again led to question seriously the validity of any procedure which takes account only of a single, isolated process; and which fails to consider the total response of the organism to a complex situation.

The total metabolic cost of noise. From all the data that have been presented in this section, we see at once that the mental work is accompanied by a consistent increase in the metabolic rate of the subject. Before going further into the question of the effects of the noise, it will be well first to determine upon some method of measuring this increase. The question which naturally arises in this connection is whether we are to calculate this increase with work by subtracting each day's resting metabolic rate from the metabolic rate during work on that day; or whether we should adopt some single measure of the subject's resting metabolism, and use this figure throughout the series as the starting point for determining the increase in the metabolic rate accompanying work. Such a measure might be the average of all the resting rates for the entire series; or else the lowest rate which was obtained on any day; the assumption here being that this figure approaches most closely to the "true" resting metabolic rate of the subject.[14]

The key to our problem obviously lies in the amount of correlation between the two functions, metabolic rate during rest and metabolic rate during work. Supposing that there existed a perfect positive correlation between the two, that is a coefficient of 1.00; then an increase in the resting metabolism on any given day would mean a corresponding increase in the metabolic rate during work, and vice versa. In such a case we would be justified in using the first method: subtracting each day's metabolic rate during rest from the working rate for that day.

[14] For a detailed discussion of this question, see Schubert (33).

Supposing, on the other hand, that a zero correlation was found between the two rates. In this case it would not necessarily follow that an increase in the resting rate would be accompanied by a similar increase in the working rate of the subject, and vice versa. In other words, a zero correlation would indicate that within the limits of normal variability, the metabolic rate during work is independent of the resting rate. Moreover, any slight change in the resting rate from day to day would be certain to distort the picture of the increase with work, since it might not be accompanied by a corresponding change in the working rate. This being true, it would seem more expedient to adopt some standard measure of the subject's resting metabolism, from which to determine the increase with work. Whether to use the average for the entire series, or the lowest obtained rate would then be a matter of choice. Should the correlation be high but negative, it would then, perhaps, be best to use the lowest figure obtainable, in order to keep the differences well above zero; otherwise it would make very little difference which measure we decided to use. This question, then becomes one of theoretical rather than practical interest; and there is no need for us to carry its analysis further in this paper.

A casual inspection of the data which have been presented makes it clear that the correlation between resting and working metabolic rates (under quiet conditions at least) is not perfect. In order to determine with exactness the degree of correlation actually existing, we have used the Product Moment Method (14). Using the data from all four series, 58 days, excluding the 18 noisy days of Series A, we obtained an r of .257 between the metabolic rates for Rest and Work I. Using the data obtained from the three series in which Subject H served, 39 days, an r of – .021 was found. Using only the 19 days in Series D, in which Subject E served, we obtained an r of .685 between Rest and Work I.

Evidently, then, there is a much closer agreement between the resting and working metabolic rates in the case of Subject E than in the case of Subject H. However, even an r of .685 does not seem high enough to justify the day-to-day method of measuring increases in metabolic rate with work, since it is not high enough to exclude the possibility of irregularity in the relationship of the two curves. Reference to Table 13 shows that such discrepancies do occur between the rates for Rest and Work I; on the fifth day (5/18), for example. Generalizing from the evidence of all four series, we may say that the two processes, Rest and Work I, are

comparatively independent of one another in their variations ($r = .257$).

Such considerations lead us to the adoption of some standard measure from which to measure each day's increase in metabolic rate with mental work; and to this end, we have decided upon the average rate calculated from the resting data of all the series in which a given subject served. We excepted, however, the resting periods of the noisy days in Series A, using, as before, only the 20 quiet days.[15]

The average resting metabolic rates for the two subjects were found to be almost identical; 37.66 ± 2.66 for Subject H; and 37.52 ± 2.96 for Subject E. Using these as our standards, we have proceeded to determine the increase and the percentage increase in the metabolic rate for the several work periods for all series. The results are given in Table 16 for quiet and noisy work periods within the several day-groups of the four series.

The data in Table 16 bring out several interesting facts. In the first place we see that the mental work is accompanied by a consistent increase in the metabolic rate, averaging 21.9 percent for all series. When these figures are compared with those obtained by investigators who experimented with physical work, one is better able to realize how slight are the changes in energy metabolism during mental work.

We see also that the increases in metabolic rate are greater on the whole during the noisy than during the quiet periods, especially in the first day-groups, before adjustment to the noise has taken place.

One cannot help feeling, however, that we have not yet told the entire story. The data which we collected on the recovery of our subjects during the last three series show very clearly that there is an after-effect of the work, and in all probability, of the noise too, which we have thus far been neglecting to a large extent in our calculations. It is necessary, therefore, to determine upon some scheme whereby this after-effect may be added to our data, in order to present a true picture of the total effect of the work and the noise.

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[15] Schubert (33), after emphasizing the necessity for using as base line "the lowest resting value obtained," nevertheless proceeds to choose as his standard a rate which was "the most representative resting value for the entire half year of measurement." Obviously this was more closely akin to the average, or rather the mode, than to "the lowest resting value obtained."

TABLE 16

SHOWING INCREASES AND PERCENTAGE INCREASE IN METABOLIC RATES ACCOMPANYING MENTAL WORK AND NOISE

		I	*II*	*III*	*IV*	*Av.*
Ser. A	Quiet	8.27	6.61	8.77	9.02	8.17
		22.9%	17.5%	23.3%	23.9%	21.9%
	Noise	11.38	9.18	8.99	9.05	
		30.1%	24.3%	23.8%	24.0%	
Ser. B	Quiet	6.59	7.70	10.16	9.24	8.42
		17.5%	20.4%	26.9%	24.5%	22.3%
	Noise	6.53	7.50	8.57	7.49	
		17.3%	19.9%	22.7%	19.8%	
Ser. C	Quiet	8.37	8.26	8.77	9.08	8.62
		22.2%	21.9%	23.3%	24.1%	22.9%
	Noise	13.15	6.23	8.88	9.40	
		34.9%	16.5%	23.6%	24.9%	
Ser. D	Quiet	7.13	9.93	6.42	7.21	7.67
		19.0%	26.4%	17.1%	19.2%	20.4%
	Noise	6.89	11.73	5.31	7.84	
		18.4%	31.3%	14.2%	19.6%	
Av.						8.22 21.9%

In order to bring the recovery data into our calculations, we have expressed our results in terms of total calories produced per square meter of body surface, rather than metabolic rate per hour. In this manner we are able to do away with a certain confusion of terminology at this point; while at the same time it is easier to insure the proper weighting for the data for each work period. Moreover, after the completion of the calculations, it is a simple matter to convert our results back to the old basis of metabolic rate, or calories per hour per square meter, if it is so desired.

The manner of converting our data to total calories per square meter may be illustrated as follows. The resting metabolic rate

of Subject H was found to be 37.66. This means that this subject, when at rest, produced 37.66 calories per hour, per square meter of body surface. We wish now to determine exactly how many calories (per square meter) were produced during the ten-minute rest-period; therefore we multiply his resting rate by 10/60, or 1/6. The answer comes out 6.28 calories per square meter. In the same way we determine the number of calories produced during each of the ten-minute work periods in Series A, basing our calculations upon the average metabolic rates for all of the quiet days in this series. We find that the subject produces 7.69 calories during Work I and 7.63 calories during Work II.

The next step is to add together the calories produced during each of the work periods. We obtain a total of 15.32 calories per square meter, produced during twenty minutes of mental work. Had the subject been merely resting during this twenty minutes, we would have expected his caloric output to have been 12.56 calories per square meter (6.28 multiplied by 2). The difference, therefore, amounts to 2.76 calories per square meter, or an increase of 22.0 percent in metabolic rate accompanying the mental work. As a check upon our work, we may compare this result with the average percentage increase in metabolic rate, as shown in Table 16; this we find to be 21.9.

Up to this point we have been merely repeating our previous work, using a different method of calculation. Had all of our work periods and recovery periods been of equal length, we should have escaped the necessity of converting our results to total scores; but now that we are ready to add in the data from the two recovery periods, our procedure justifies itself.

Inasmuch as we have no control data on recovery during quiet days for Subject H, we are obliged to take our normal standard from the experimental data of Series B and C. However, we may obtain our norm from the end of these series, where it seems reasonably certain that adjustment to the noise has taken place; and it is safe to assume that such a standard would agree well enough with a control if we had it. Accordingly, we have taken as our norm for Recovery 1 without noise, the average of the last two days of Series B and the last two days of Series C. The norm for Recovery 2 is the same as Rest; *i.e.*, 6.28 calories per square meter.

Averaging the above-mentioned data, we obtain as our norm for Recovery 1, 42.00 calories per hour per square meter. To find the total output during the three minutes of this period, we must

multiply this by 3/60, which gives us 2.10 calories per square meter. The predicted value for a corresponding period of rest would be $37.77 \times 3/60$, or 1.88 calories per square meter. The difference, 0.22 calories per square meter, indicates the additional energy expenditure during the work which is not included in the data for the work periods proper, and which must be added to the total increase with work. Since this debt does not carry over into Recovery 2, there is nothing to add here.

Continuing our calculations, then, we find that 15.32 plus 0.22 equals 15.54 calories per square meter—the total expenditure during twenty minutes of mental work under conditions of quiet. This raises our percentage increase in energy expenditure from 22.0 percent to 23.8 percent; a slight increase, it is true; but nevertheless one which it is worth while to take into consideration.

Even now we must recognize certain limitations in our picture of the total energy "cost" of the work. Our calculations are based upon what are essentially the average metabolic rates over greater or less periods of time; and they do not, therefore, take account of every fluctuation which might occur from minute to minute. To this extent at least, they are not literally *total* figures; but rather *predicted* totals, calculated from samples of the metabolic rate taken from various points along the work curve.

Another point to be borne in mind is the fact that our recovery data were collected from two periods which differed considerably in length; a three-minute period, followed by a ten-minute period. Had we used instead of these two periods, four three-minute periods, it is possible that we might have had a slightly higher figure to add to the total calories produced during work. If such was the case, this additional figure was swallowed up in the general average for the longer recovery period. It is not probable, however, that we lost a great deal in this manner, since the increase with the work was itself so slight; and the recovery process, therefore, must necessarily have been rapid.

With these reservations in mind, we may accept our data as giving a fairly accurate picture of the total increase in energy expenditure accompanying mental work; and proceed to the investigation of the effects of the noise upon this total.

In Table 17 is shown the "cost" of noise in calories per square meter over twenty-minute periods of work. Each of the series has at the top the control data, for work without noise; and below the corresponding data for each of the four day-groups. Series A.

of course, lacks the added calories for recovery periods, which have been added for each of the remaining three series.

As already explained, the value for Rest is constant for a given subject throughout all series in which he served; and the same is true of the "Norm" or value for Work I, in Series B, C, and D, which is the average for all Work I under quiet conditions. We thus assumed a constant norm for quiet work in order better to bring out the effect of noise.

In the case of Subject E, the recovery norms consist of the average for the last four days of his adjustment period. In all cases where the obtained values for Recovery 2 were lower than the value for Rest, the latter was used, and nothing was subtracted.

TABLE 17

SHOWING TOTAL COST OF WORK AND OF NOISE; ALSO COST PER PROBLEM, IN CALORIES PER SQUARE METER, IN SERIES A, B, C, AND D

	Cost of Wk. (cal. per sq. m.)	*Difference (Noise–Quiet)*	*% Difference*	*Cost per Prob.*	
Norm	2.76	....	22.0	.058	
I	3.80	1.04	37.7	.083	
II	3.06	0.30	10.9	.062	A
III	3.00	0.24	8.7	.064	
IV	3.01	0.25	9.1	.061	
Norm	2.98	....	23.8	.063	
I	3.17	0.19	6.4	.072	
II	3.58	0.60	20.1	.080	B
III	3.18	0.20	6.7	.071	
IV	2.93	– 0.05	– 1.7	.065	
Norm	2.98	....	23.8	.063	
I	4.99	2.01	67.4	.108	
II	2.71	– 0.27	– 9.1	.060	C
III	2.99	0.01	0.3	.065	
IV	3.48	0.50	16.8	.073	
Norm	2.73	....	21.8	.036	
I	2.50	– 0.23	– 8.4	.035	
II	3.32	0.59	21.6	.045	D
III	2.48	– 0.25	– 9.2	.032	
IV	2.76	0.03	– 1.1	.035	

Attention is called to the several columns of figures in Table 17. The first of these records the increase in calories produced with the work in the case of the norm; and with the work plus the noise in each of the four day groups. The column headed *Difference* gives the difference between increase in energy expenditure during mental work alone (norm) and the increase during mental work

plus noise. The increase with noise, over and above the increase for the norm can be attributed to the noise itself, since we have held constant all other conditions; and since we have seen that, other things being equal, there are no consistent differences between the first and second ten minutes of work (Series A).

In the third column the difference due to the noise is expressed as a percentage of the norm (column 1). From it, we see that the general effect of the noise is to increase the energy expenditure accompanying mental work by amounts varying approximately from 1 to 67 percent, depending upon the degree of adjustment of the subject. In a few cases, however, the energy expenditure is actually less under the noisy than under the quiet conditions. These negative differences range as high as -9.2 percent, and we may infer that differences due to chance might also run that high in the other direction. This leads us logically to set variations of 10 percent as our criterion of adjustment to the noise, and to disregard all smaller differences in either direction.

Thus we see that in each series, adjustment to the noise has taken place by the end of the second day-group. Series B and Series D are peculiar in that both show the greatest noise effects in the second rather than in the first day-group. This fact results in a rather irregular curve of adjustment to the noise; and can be accounted for only by the small number of cases within any given day-group in each series.

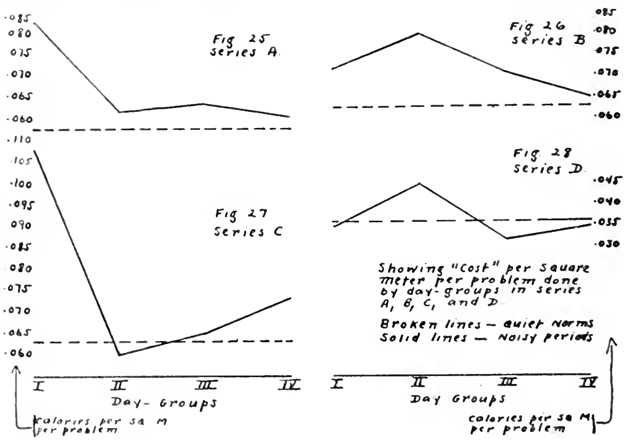
There yet remains one further step that we may take in studying the effects of noise on metabolism and mental work. We are now in a position to bring together our two sets of results, so as to express the metabolic data on work in terms of problems done, or calorific increase per square meter per problem.

In the last column of Table 17 are presented the data on increase per problem during noisy periods, together with the increase per problem during quiet periods, for the four day-groups of each series. These data were obtained by dividing the calorific gain for twenty minutes of work by the number of problems worked, using the actual number done over the twenty-minute period. We have used constant values for our norms throughout a given series.

The same data are presented graphically in Figures 25–28. The figures for work with noise are in general considerably higher during the first and second day-groups; while thereafter they tend to decrease or to remain fairly constant. The process of adjustment to the noise is noticeable in each of the four experimental series.

In Series C and D, adjustment is marked by overlapping of the curves from quiet and noisy work.

In the light of this further evidence, we must add somewhat to our summary of the metabolic findings on noise. We have seen that when we take into consideration the "hangover," the effects of the noises become even more apparent than before. Considering energy expenditure alone, as measured in terms of increase in total calory production during work, we found that the noise tended to augment this to some extent. When expressed in terms of problems done,



FIGS. 25–28

there is an initial effect in the direction of a still more marked increase in "cost" with noise, followed by a rapid adjustment on the part of the subject. The initial increase per problem caused by the noise amounted in some cases to as much as a four-hundredths of a calory per square meter. Although this may seem insignificant at first thought, it must be remembered that it is expressed in units *per problem;* moreover that the calories are expressed *per square meter of body surface.*[16]

Evidently, then, the first effect of the noise is to increase the energy expenditure during work, at the same time lowering the

[16] The term "cost" as used in this paragraph is simply a convenient label to indicate that the increase in calories during work has been expressed in terms of units of work, or problems done. We do not mean thereby to imply that we have actually measured the cost of mental work—a problem with ramifications far beyond the scope of the present study.

output. This makes for a rather high "cost" per problem, when compared with the corresponding norm. Very soon, however, as adjustment on the part of the subject takes place, we find output returning gradually to normal. This, in itself, would lower the "cost" per problem, and at the same time it is supplemented by a tendency towards decreased energy expenditure.

3. *Other Measures of Metabolism*

In computing the metabolic rates of our subjects, it was necessary to carry our calculations through a number of steps, which involved the use of many factors, such as the rate of absorption of oxygen, the rate of production of carbon dioxide, the ventilation

TABLE 18

SHOWING TOTAL INCREASE WITH WORK AND WITH NOISE; ALSO INCREASE PER PROBLEM, IN CC. OF OXYGEN, DURING SERIES A, B, C, AND D

		Increase with Work cc. of O_2	*Difference Noise–Quiet*	*% Diff.*	*Increase per Problem cc. of O_2*
	Norm	871	......	19.8	18.2
	I	1284	413	47.4	27.9
	II	992	121	13.9	20.2
A	III	941	70	8.0	20.0
	IV	952	81	9.3	19.4
	Norm	950	......	21.5	19.8
	I	809	−141	−14.9	18.4
	II	917	− 33	− 3.5	20.4
B	III	943	− 7	− 0.7	20.9
	IV	836	−114	−12.0	18.6
	Norm	950	......	21.5	19.8
	I	987	37	3.9	21.4
	II	873	− 77	− 8.1	19.4
C	III	926	− 24	− 2.5	20.1
	IV	989	39	4.1	20.6
	Norm	974	......	18.5	12.6
	I	904	− 70	− 7.2	12.7
	II	1236	262	27.0	16.9
D	III	911	− 63	− 6.5	11.8
	IV	1080	106	10.9	13.7

rate, and the like. Inasmuch as many investigators have employed these factors themselves as indicators of the metabolic rate, it will be well, perhaps, briefly to review our findings here, in regard to the more significant of these.

Oxygen absorbed. From the percentage of oxygen in the expired air, and the known composition of the air inspired, the per-

centage of oxygen absorbed by the organism is quite easily computed. Given the ventilation rate, or volume of air breathed out per minute, we are able to determine the rate of oxygen absorption, in cc. per minute. These data have been worked up in the manner already described, and the results are presented in Table 18. From it we see that the changes accompanying the work, when measured in terms of total cc. of oxygen absorbed over the twenty-minute period are in fairly close agreement with our results on metabolic rate. As a matter of fact, the percentage increase in oxygen absorbed is, for all practical purposes, identical with the increase in calories per square meter.

The increased "cost" of work under noisy conditions is also brought out by the oxygen absorption, though the differences now are in some cases lower than before, never exceeding 47.4 percent. The process of adjustment also shows itself.

Ventilation. We have already defined ventilation rate as liters of air expired per minute by the subject. Ventilation, or total ventilation, therefore, means the total volume of air expired—during the twenty-minute work period, in this case. Ventilation is measured in liters.

Table 19 gives our data on the changes accompanying the work and the noise, in terms of the ventilation of our subjects. The general trend of the results is in fairly close agreement with our other measures; though figures for quiet are somewhat lower, and those for noisy work somewhat higher at first. From Series B and C, we notice that the inclusion of the data on Recovery affects the results very little, if at all. Indeed the general effect of the noise itself tends to be almost completely masked in these series. This is largely due to the fact that the base from which we measured increases in ventilation accompanying the work and the noise was obtained by averaging the values from Series A, B, and C. As mentioned above (under Apparatus), the type of gas mask worn by the subject was changed (about the middle of Series A), and the new mask resulted in a somewhat lower ventilation, which occurred uniformly in all work periods. Thus, in Series B and C, the increases were measured from an unduly high base; and hence the masking of the noise effects there.

Respiratory Quotient. The respiratory quotient, or RQ, to which we have reference here, is the non-protein RQ. That is to say, it is calculated without determining by analysis the nitrogen content of the urine. Experience has shown that it is possible to

TABLE 19

SHOWING TOTAL INCREASE IN VENTILATION WITH WORK AND WITH NOISE; ALSO INCREASE PER PROBLEM IN LITERS OF AIR EXPIRED, IN SERIES A, B, C, D

		Gains with Work, Liters	*Difference Noise–Quiet*	*% Difference*	*Gain per Problem*
	Norm	20.6	....	16.8	0.43
	I	39.3	18.7	90.7	0.81
	II	38.4	17.8	86.4	0.78
A	III	21.3	00.7	3.4	0.45
	IV	21.9	1.3	6.3	0.45
	Norm	19.7	....	16.0	0.42
	I	20.3	0.6	3.0	0.46
	II	18.0	− 1.7	− 8.6	0.40
B	III	22.0	2.3	11.6	0.49
	IV	21.1	1.4	7.1	0.47
	Norm	19.7	....	16.0	0.42
	I	19.9	0.2	1.0	0.43
	II	19.2	− 0.5	− 2.5	0.43
C	III	18.6	− 1.1	− 5.6	0.40
	IV	23.6	3.9	19.8	0.49
	Norm	21.6	....	14.3	0.28
	I	25.2	3.6	16.7	0.36
	II	43.4	21.8	100.9	0.59
D*	III	16.9	− 4.7	−21.8	0.22
	IV	22.7	1.1	5.1	0.29

* Standard for Recovery—1 Av. of Recovery—1 in III and IV.

obtain with the non-protein RQ results which, for all practical purposes, differ little, if at all, from those obtained by the more complicated and laborious procedure; and indeed the latter is seldom employed in experiments such as those we are now describing.[17]

The RQ is defined as the ratio of carbon dioxide produced[18] to oxygen absorbed; and it is determined from the percentages of each which are present in the expired air. In the present experiment we found a number of well-marked changes in RQ accompanying the work and the noise. These changes, however, were so variable in their direction and magnitude, that it seemed expedient to return to our original manner of presentation, *i.e.*, as a composite work curve, rather than to calculate increases and decreases with work and noise.

In Table 20, therefore, we give the RQs by work periods in the four day-groups for each of the experimental series. In all cases

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[17] Hawk and Bergeim, *op. cit.*

[18] Inasmuch as the carbon dioxide data are included in the RQ, we have not presented the former measures separately here.

TABLE 20

SHOWING CHANGES IN RESPIRATORY QUOTIENT BY DAY-GROUPS IN SERIES A, B, C, AND D

	Group		*Rest*	*Wk. I*	*Wk. II*	*Wk. III*	*Rec. 1*	*Rec. 2*
A	I	Q.	0.79	0.79	0.79			
		N.	0.78	0.77	0.76			
	II	Q.	0.80	0.80	0.81			
		N.	0.77	0.80	0.78			
	III	Q.	0.81	0.80	0.81			
		N.	0.80	0.81	0.81			
	IV	Q.	0.78	0.79	0.79			
		N.	0.79	0.81	0.81			
B	I		0.84	0.82	0.84	0.84	0.84	0.84
	II		0.82	0.80	0.80	0.81	0.81	0.78
	III		0.81	0.80	0.80	0.82	0.82	0.83
	IV		0.81	0.81	0.80	0.82	0.80	0.83
C	I		0.79	0.80	0.72	0.81	0.73	0.81
	II		0.77	0.80	0.78	0.79	0.79	0.79
	III		0.79	0.80	0.79	0.80	0.76	0.79
	IV		0.77	0.78	0.78	0.80	0.84	0.81
D	I		0.79	0.76	0.83	0.82	0.78	0.77
	II		0.81	0.96	0.90	0.80	0.80	0.73
	III		0.77	0.86	0.78	0.80	0.79	0.76
	IV		0.80	0.90	0.87	0.86	0.81	0.79

except Series D, we see that the subject's RQ changes very little, if at all during the quiet work. In D, there is a more marked change, usually in the direction of an increased RQ during work, except in the first day-group, where the RQ decreased.

The first effect of the noise was in most cases in the direction of a decreased RQ, followed by a gradual increase in the succeeding day-groups. After adjustment occurs, the RQ may even be higher in noisy than in quiet periods. This is true in Series A and in Series C; in both of which the subject was faced with a noise which was new to him. In Series B the RQ was unaffected by the noise, for a change amounting to not more than two or three points has no significance. It must be remembered, however, that by the time this series was run, Subject II had already become at least partially adjusted to the noise. In this case B would seem to be a continuation of Series A, inasmuch as we have seen that adjustment to noise tends to raise the RQ.

Series D shows little agreement with any of the other series. In the first day-group of this series, the effect of the noise was to raise

slightly the RQ; at least so it would seem at first glance. On the other hand, it is easily possible that the seemingly higher RQ with noise in this group was due to the abnormally low RQ for Work I. If the RQ for Work I had been as high in this group as in each of the three remaining groups, our results with the noise would have appeared much more harmonious and consistent. Then it might have been possible to say that the first effect of the noise was in the direction of a lowered RQ, followed by a more gradual return to normal; and inasmuch as the figure for Work I does appear to be anomalous, we may well accept this interpretation.

Generalizing from our data on the RQ, we may say that during the work itself the values for this factor either remain unchanged, to all practical purposes; or else they increase approximately 10 to 12 points, as in Series D. This effect appears to be constant for a given subject. When the noise is introduced, however, there occurs an immediate drop in the working RQ, followed by a return to "normal" during the subsequent work periods. The progressive elimination of these changes, moreover, follows the course of adjustment to the noise, as we have traced it in connection with our other measures.

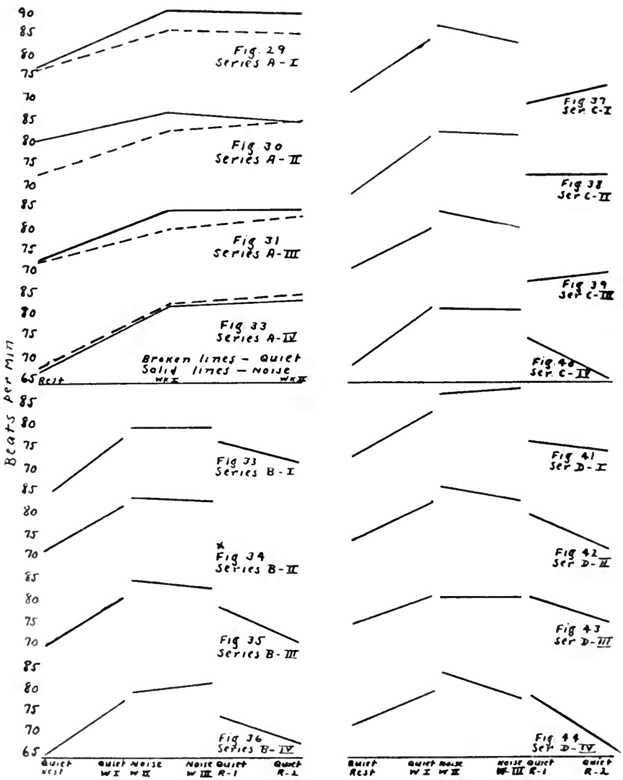
We have seen that the increased metabolic rate with noise in the earlier stages of a series is characterized by increases in rate of oxygen absorption, and also by increases in ventilation. The decreases in RQ, therefore, clearly point to the fact that these changes are not completely paralleled by the rate of elimination of carbon dioxide, the rate of increase of which lags somewhat behind that of the oxygen.

4. *Heart Rate*

The heart rate of our subjects was measured by means of a cardiotachometer, which registers the beat alone, without regard to its force or magnitude. In the present experiment, heart beats were recorded kymographically, on the same drum which contained the breathing curves and the time line. Our data are expressed in terms of beats per minute; and they were obtained by counting the total number of beats recorded over a period of one minute on the kymograph sheet. In a few instances it was necessary to count the beats over half-minute periods, doubling their number, in order to determine the rate per minute; but such procedure was the exception rather than the rule.

Our records cover the following periods within each experimental sitting: the rate for Resting, obtained by counting the beats

over one-minute periods at the beginning and at the end of Rest, and averaging together the two counts; the rate during Work I, taken during the first and the fifth minutes of work; and the rate during Work II, taken during the eleventh, fifteenth and nineteenth



FIGS. 29–44

Showing Changes in Heart Rate in Successive Work Periods by Day-Groups in Series A, B, C, D.

minutes of the work period. In Series B, C, and D, the rate as measured during the eleventh minute represents Work II; while the average of the measures for the fifteenth and the nineteenth minutes together represents Work III. In these last three series,

moreover, the rate during Recovery was measured immediately following the cessation of the work (Recovery 1), and again towards the end of Recovery 2.

Inasmuch as the heart rate was found to remain quite constant throughout a given work period, we decided to combine our data as just described, giving a single average measure for each period and thus rendering our results directly comparable to those already presented.

The data on heart rate for Series A are presented in Table 21 and in Figures 29–32.

TABLE 21

SHOWING THE HEART RATE FOR SUCCESSIVE QUIET AND NOISY DAYS IN SERIES A

Quiet Days				*Noisy Days*			
Date	*Rest*	*Work I*	*Work II*	*Date*	*Rest*	*Work I*	*Work II*
1/13	73	81	82	1/15	82	99	99
1/16	75	85	83	1/17	80	84	83
1/19	74	86	85				
1/20	82	89	87				
1/21	79	86	85	1/22	70	87	85
Av.	76.6	85.4	84.4	Av.	77.3	90.0	89.0
1/23	78	86	90	1/24	87	86	83
1/26	70	85	85	1/27	80	94	92
				1/29	76	81	81
1/30	74	81	80	1/31	78	84	81
2/2	70	79	84				
Av.	73.0	82.8	84.8	Av.	80.3	86.3	84.3
2/4	68	77	81	2/5	70	81	83
				2/7	74	84	85
2/16	74	82	83	2/17	74	87	89
2/18	76	84	87	2/19	78	91	88
2/24	72	77	80	2/25	76	76	78
				2/26	66	86	82
Av.	72.5	80.0	82.8	Av.	73.0	84.2	84.2
2/27	62	78	79	2/28	66	75	82
3/4	84	90	95	3/5	67	89	90
3/6	62	81	82	3/7	70	83	80
3/9	66	83	81	3/10	66	78	81
3/11	69	84	89	3/13	70	89	86
Av.	68.6	83.2	85.2	Av.	67.8	82.8	83.8

From the results in this table, it is evident that, as in the case of metabolic rate, the noise at first produced a marked effect upon the heart rate, increasing it somewhat for the first ten days or more. Thereafter the rates for noisy and quiet days begin to overlap more

and more, until, towards the end of the series, there is no longer any clear-cut distinction between the two sets of results. From the data in Table 21, moreover, we see a close correlation between the heart rate in the first and second work-periods; both of which are above the corresponding resting rates.

From Figures 29–32 we see very clearly the changes in heart rate accompanying, first the work itself, and finally, the noise. In all cases the work alone, as indicated by the broken line is associated with a marked increase in the rate; an increase which tends to be slightly more marked towards the end than at the beginning of the work—at least in the last three day-groups. When the noise is introduced, we see a further increase in heart rate, during both work periods; while the process of adjustment is very clearly indicated from one day-group to another. In Group IV, the average heart rate for work on noisy days is just below that for quiet days; a criterion of perfect adjustment. It is also worthy of note in passing, that the adjustment to the noise appears first in Work II, and goes forward somewhat more rapidly in this period than in Work I. The close parallelism between the work curves for quiet and noisy days is another interesting point which it will be well to bear in mind.

TABLE 22

Showing Changes in Heart Rate During Several Periods on Successive Days in Series B

Date	*Quiet Rest*	*Quiet Work I*	*Noisy Work II*	*Noisy Work III*	*Quiet Rec. 1*	*Quiet Rec. 2*
3/25	......	......	......	......	......	......
3/26	60	76	78	80	68	......
3/27	68	80	82	82	96	72
3/28	64	76	80	78	66	......
Av.	64.0	77.3	80.0	80.0	76.7	72.0
3/30	76	84	84	84	72	......
3/31	67	80	84	82	......	......
4/1	73	80	84	83	74	......
4/2	72	84	84	84	......	......
Av.	72.0	82.0	84.0	83.3	73.0	......
4/6	67	73	86	85	78	66
4/7	76	82	......		......	......
4/8	64	86	88	84	76	72
4/9	74	84	82	82	84	76
Av.	70.3	81.3	85.3	83.7	79.3	71.3
4/15	67	82	78	80	78	68
4/16	60	76	......	......	72	64
4/17	70	76	82	84	74	74
Av.	65.7	78.0	80.0	82.0	74.7	68.7

Let us now turn to the consideration of the changes in heart rate occurring during the three remaining experimental series. The data for Series B are found in Table 22 and Figures 33–36.

From the day-to-day data on this series we see that the heart rate during Work II and Work III (the noisy periods) tends to remain somewhat higher than the rate for Work I from beginning to end, with but two exceptions. The same fact is brought out even more plainly in Figures 33–36, where the data are averaged in day-groups. Slight though the change may be, we are inclined to attribute it to the effects of the noise rather than to any possible cumulative effect of the work by itself, especially since the increase is more marked in Work II rather than in Work III in all except the last day-group.

Next in order are the data on heart rate in Series C. These are presented in Table 23 and in Figures 37–40.

TABLE 23

Showing Changes in Heart Rate During Various Periods on Successive Days of Series C

Date	*Quiet Rest*	*Quiet Work I*	*Noisy Work II*	*Noisy Work III*	*Quiet Rec. 1*	*Quiet Rec. 2*
4/20	71.0	83.0	86.0	82.0	68.0	72.0
4/21	68.0	81.0	82.0	81.0	72.0	72.0
4/22	71.0	80.0	84.0	80.0	68.0	70.0
4/23	69.0	82.0	82.0	81.5	75.0	66.0

From the table and its accompanying figures we obtain a picture which closely resembles that in Series B; during the first three days, at least. There is a perceptible increase in heart rate with the introduction of the noise (Work II); and this gain tends to disappear during the last work period (Work III). In Series C, however, there is some evidence of adjustment on the part of the subject; for the results on Day 4 show no appreciable gain in heart rate during work, even though the noise is still present. The figures for the two Recovery periods, moreover, undergo marked changes throughout the series. All of this would seem to indicate that it is the noise rather than the work alone which is affecting the heart rate of our subject here.

The data for heart rate in the experiments with Subject E, Series D, are given in Table 24, and Figures 41–44. In this case the day-to-day results clearly show a higher heart rate with work during noisy periods at first, followed by a gradual adjustment,

which appears to have been fairly complete by the twelfth day. Except at the beginning, moreover, the higher rate occurs during Work II, rather than Work III, as in most of the preceding series; and this would seem clearly to indicate that the higher rate could not have been due to cumulative effects related to work alone. Furthermore it is to be noted that, from the twelfth day on until the end of the series, the heart rate during Work II and Work III is not consistently higher than the rate during Work I.

TABLE 24

Showing Changes in Heart Rate During Various Periods for Successive Days in Series D

Date	*Quiet*	*Quiet*	*Noisy*	*Noisy*	*Quiet*	*Quiet*
	Rest	*Work I*	*Work II*	*Work III*	*Rec. 1*	*Rec. 2*
5/11	68	84	82	93	74	72
5/12	76	83	88	86	80	74
5/13	75	84	96	90	76	76
5/14	76	82	84	86	87	76
5/18	72		....	.		
Av.	73.4	83.3	87.5	88.8	76.8	74.5
5/19	78	83	92	85	84	74
5/20	72	83	84	86	78	72
5/21						
5/22	73	85	84	80	78	72
5/23	74	81	86	81		70
Av.	74.3	83.0	86.5	83.0	80.0	72.0
5/25	74	81	80	80	84	80
5/26	73	82				
5/27	84	87	90	87	92	81
6/4	74	78	80	78	75	71
6/5	72	81	76	80	74	71
Av.	75.4	81.8	81.5	81.3	81.3	75.8
6/6	68	76		74	68	64
6/8	72	85	81	81	85	72
6/9	76	86	90	82	88	69
6/10	74	73	82	75	75	66
Av.	72.5	80.0	84.3	78.0	79.0	67.8

When the data for Series D are averaged by day-groups, we obtain results which are in striking agreement with those from Series C. The only difference worth noting is the fact that in D one sees no marked changes in the recovery process from one day-group to another; and this, it will be remembered, confirms our findings on metabolic rate in the same series.

We come now to the question of the effects of the noises upon variability of heart rate in Series A, B, and D. These data, ex-

pressed as usual in terms of coefficients of variability, will be found in Table 25.

TABLE 25

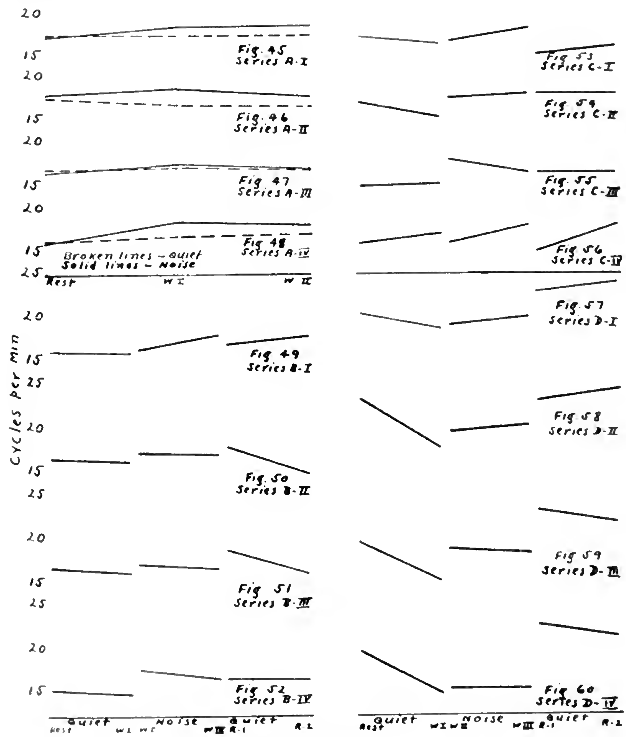
Showing Changes in Coefficients of Variability for Heart Rate, in Series A, B, and D

Group		Quiet Days				Noisy Days		
		Rest	*Work I*	*Work II*		*Rest*	*Work I*	*Work II*
A	I	4.44	3.06	2.13		6.86	7.24	7.97
	II	4.52	3.50	4.28		5.11	5.57	5.44
	III	4.14	3.89	3.38		5.30	6.32	4.39
	IV	12.38	4.82	6.92		2.65	6.88	4.42
		Rest	*Work I*	*Work II*	*Work III*			
B	I	8.13	2.46	2.00	2.14			
	II	5.14	2.44	0.00	1.23			
	III	6.97	6.16	2.93	1.43			
	IV	6.38	3.71	2.50	2.57			
D	I	4.23	1.44	6.17	3.27			
	II	3.10	1.81	3.81	3.01			
	III	5.54	3.55	7.36	4.17			
	IV	4.14	6.96	4.75	4.49			

From the table we see that, under quiet conditions, the variability is lowered during the work approximately 0.5 to 7.0 points, with but one exception. No consistent differences between Work I and Work II are observable in Series A. On the noisy days, however, the variability during work was increased over the corresponding resting value by about the same amount that it was lowered on the quiet rays. With the exception of the first day-group, moreover, the effect of the noise is more pronounced during Work I than during Work II; and the only evidence of adjustment to the noise is to be found in Work II.

In series B we find the effect of the noise operating in a direction exactly opposite to that of Series A. Here, as before, the work under quiet conditions is characterized in general by a decreased variability. When the noises are introduced, however, the result is a still further decrease in variability instead of an increase; and the relationship between Work I on the one hand, and Work II and III on the other, remains unchanged throughout the series. No large or consistent difference between variability in two noisy work periods are to be observed during this series; nor is there much evidence of progress in the adjustment process, un-

less, indeed, we take it that the subject was already adjusted to the noise, and remained so throughout the series. The strongest evidence in favor of such a hypothesis lies in the fact that the effect of the noise seems to be reversed in Series B; and this argument is strengthened somewhat by our experience with other measurements in this same series.



FIGS. 45–60
Showing Changes in Breathing Rate in Successive Work Periods by Day-Groups in Series A, B, C, D.

As in most of the other cases, the data for Series D are in very close agreement with those for Series A. In respect to variability of heart rate, this agreement takes the shape of a decrease in the coefficients during work under quiet conditions; and an increase

under noisy conditions—during Work II. Variability during Work III closely approximates the resting values, though it remains higher than Work I, except in the last day-group, which has an abnormally high value for variability during Work I. Still, it must be remembered that the size of our day-groups was so small that a single case might very easily affect the variability at any time. All things considered, there is certainly good evidence in favor of adjustment to the noise in Series D; for all of the values have drawn very close together by the end of this series.

TABLE 26

SHOWING CHANGES IN BREATHING RATE FROM DAY TO DAY IN SERIES A

Date	*Quiet Days*			*Noisy Days*			
	Rest	*Work I*	*Work II*	*Date*	*Rest*	*Work I*	*Work II*
1/13	17.0	17.0	16.3	1/15	18.0	18.5	18.0
1/16	18.0	15.5	17.0	1/17	17.0	19.0	19.0
1/19	17.0	18.0	18.3				
1/20	18.0	17.5	17.3				
1/21	16.0	18.0	17.8	1/22	16.0	17.0	18.3
Av.	17.2	17.1	17.3	Av.	17.0	18.2	18.4
1/23	18.0	16.5	17.3	1/24	19.0	19.0	18.0
1/26	18.0	18.5	17.8	1/27	18.0	19.5	18.8
1/28	17.0	16.5	15.8	1/29	17.0	17.0	15.7
1/30	18.0	16.5	16.0	1/31	17.0	18.5	18.0
2/2	17.0	16.0	17.0				
Av.	17.6	16.8	16.7	Av.	17.8	18.5	17.6
2/4	17.0	16.5	16.3	2/5	17.0	17.5	17.3
2/6	....	....	....	2/7	17.0	15.5	14.3
2/16	17.0	16.0	16.0	2/17	16.0	18.0	16.8
2/18	17.0	18.5	17.3	2/19	16.0	20.0	18.7
2/24	17.0	17.5	17.0	2/25	16.0	17.5	16.7
				2/26	17.0	16.5	18.0
Av.	17.0	17.2	16.9	Av.	16.5	17.5	17.0
2/27	16.0	17.0	17.3	2/28	16.0	18.5	18.0
3/4	17.0	16.0	17.8	3/5	16.0	18.5	19.0
3/6	16.0	17.5	17.3	3/7	16.0	17.5	18.8
3/9	17.0	16.5	17.3	3/10	16.0	18.5	18.0
3/11	16.0	17.5	16.3	3/13	16.0	19.0	17.0
Av.	16.4	16.9	17.2	Av.	16.0	18.5	18.1

By way of summarizing our findings with heart rate, we may say that these results are in close agreement with the data on metabolic rate. This is exactly what one would expect to find.[19] In our own experiments we observed that the work alone was accompanied by an increase in the heart rate of the subjects, ranging from 8 to

[19] The relationship between metabolic rate and heart rate in the case of purely physical work has been investigated and described by Schubert (33).

13 beats per minute; while the noises, in the earlier stages, increased the working rate as much as 5 beats per minute, on the average. During the subsequent day-groups, moreover, there was a picture of adjustment to the noises, to a greater or less extent. In no case, however, did the adjustment in this process appear as complete as in the case of metabolic rate.

5. *Breathing Rate*

Breathing rate, in cycles per minute, was measured in the same manner and over the same periods as the heart rate of our subjects. These data are presented in Tables 26 to 29, and in Figures 45–60.

From these data it is apparent that our results on breathing rates are rather inconsistent: at least in so far as changes accompanying the work, independently of the noises, are concerned. In Series A, we find that the breathing rate tended sometimes to increase and sometimes to decrease during work; these tendencies, moreover, reversing themselves at times from one work period to the other. In Series B the changes accompanying the work were uniformly in the direction of a slightly decreased breathing rate; while in Series C the rate was twice decreased and twice increased.

TABLE 27

CHANGES IN BREATHING RATE FROM DAY TO DAY IN SERIES B

Date	*Quiet*	*Quiet*	*Noise*	*Noise*	*Quiet*	*Quiet*
	Rest	*Work I*	*Work II*	*Work III*	*Rec. 1*	*Rec. 2*
3/25	15.0	16.5	15.0	17.5	17.0	....
3/26	16.0	16.0	17.0	17.8	18.0	....
3/27	17.0	16.5	18.0	18.0	15.0	18.0
3/28	17.0	15.5	16.0	19.5	18.0	....
Av.	16.3	16.2	16.5	18.2	17.0	18.0
3/30	16.0	16.5	17.0	17.0	17.0	....
3/31	17.0	15.5	16.5	17.0	...	....
4/1	15.5	15.8	17.0	18.0	19.0	15.0
4/2	18.0	18.3	19.0	17.5	.....	....
Av.	16.6	16.4	17.4	17.2	18.0	15.0
4/6	17.0	15.8	17.0	16.0	18.0	17.0
4/7	17.0	15.0	16.5	16.0	18.0	....
4/8	15.0	16.8	17.0	18.0	19.0	15.0
4/9	18.0	18.0	19.0	17.5	20.0	17.0
Av.	16.8	16.4	17.4	16.9	18.8	16.3
4/15	14.0	15.3	18.0	16.0	15.0	16.0
4/16	15.0	15.3	17.5	17.3	17.5	16.0
4/17	17.5	15.0	18.0	16.0	18.0	18.0
Av.	15.5	15.0	17.8	16.8	16.8	16.7

Only in the last named series did this change amount to as much as one cycle per minute, however. In Series D, on the other hand, the work was marked always by decreases in the rate of breathing, and the amount of change generally ran as high as five cycles per minute.

TABLE 28

SHOWING CHANGES IN BREATHING RATE FROM DAY TO DAY IN SERIES C

Date	*Quiet*	*Quiet*	*Noise*	*Noise*	*Quiet*	*Quiet*
	Rest	*Work I*	*Work II*	*Work III*	*Rec. 1*	*Rec. 2*
4/20	17.0	16.3	16.5	18.0	15.0	16.0
4/21	17.0	15.5	17.5	18.0	18.0	18.0
4/22	15.0	15.3	18.0	16.5	16.5	16.5
4/23	16.0	17.0	16.0	18.0	15.0	18.0

When the noise accompanied the work, there always followed a sharp increase in breathing rate in Series A. This increase ranged from 0.5 to 2.5 cycles per minute during Work I. During Work

TABLE 29

SHOWING CHANGES IN BREATHING RATE FROM DAY TO DAY IN SERIES D

Date	*Quiet*	*Quiet*	*Noise*	*Noise*	*Quiet*	*Quiet*
	Rest	*Work I*	*Work II*	*Work III*	*Rec. 1*	*Rec. 2*
5/11	19.0	16.0	18.0	17.0	25.0	20.0
5/12	20.0	19.0	19.0	22.8	23.0	26.0
5/13	23.0	20.0	20.0	22.5	20.0	30.0
5/14	18.5	21.0	19.0	18.5	24.0	20.0
5/18	22.0	17.8	20.0	19.8	23.0	24.0
Av.	20.5	18.8	19.2	20.1	23.0	24.0
5/19	22.0	17.0	16.5	18.5	23.0	24.0
5/20	21.0	17.0	22.0	19.0	26.0	26.0
5/21	22.0	17.8	19.0	22.5	18.0	28.0
5/22	26.0	17.0	20.5	21.0	25.0	24.0
5/23	26.0	20.5	20.0	21.0	....	20.0
Av.	23.4	17.9	19.6	20.4	23.0	24.4
5/25	20.0	16.5	24.0	20.3	23.5	24.0
5/26	19.5	15.0	16.0	19.5	23.0	22.0
5/27	19.0	14.5	21.0	18.5	24.0	19.0
6/4	19.0	14.5	16.0	14.5	23.0	24.0
6/5	20.0	15.0	17.5	16.5	23.0	20.0
Av.	19.5	15.1	18.9	18.4	23.3	21.8
6/6	23.0	17.8	18.0	14.3	22.5	18.5
6/8	19.0	16.0	15.5	17.5	18.0	23.0
6/9	20.0	14.0	14.5	14.5	16.0	23.0
6/10	17.5	12.8	14.0	15.8	24.0	21.0
Av.	19.9	15.1	15.5	15.5	22.6	21.4

II there was a slight falling off in breathing rate once more, ranging from 0.1 to 0.8 cycles per minute less than the rate during the first work period. There was very little evidence of adjustment to the noise during this series.

In Series B we observed a very slight, practically insignificant falling off in breathing rate with work during Work I—the quiet work period. When the noises began there was an instant rise in rate, which then began to exceed the corresponding resting values. With the exception of the first day-group, breathing rate was always higher during Work II than during Work III. The extent of the changes which we have described for Series B was about the same, on the average, as the extent of those in Series A; and here as before, one is able to find very little evidence of adjustment to the noise. The recovery data on breathing in all series appeared too incomplete and erratic to warrant discussion.

The results for Series C resemble those for Series B in many respects, except that in this series the rate was higher during Work III than during Work II in three out of the four days. On the last day of Series C, the breathing rate during Work II was exactly equal to the resting rate; though in the absence of further data it does not seem safe to conclude that adjustment had actually taken place.

Series D gives us our most consistent picture of the effects of noise and the process of adjustment in breathing rate. Here the work itself was accompanied by decreases in breathing rate ranging from 1.5 to 5.0 cycles per minute; while the noise increased the working rate from 0.5 to 4.0 cycles per minute during Work II. In Work III the working rate increased another cycle during the first two-day groups. During the last day-groups breathing rate remained practically unchanged from Work II to Work III. During the last day-group, the breathing rate during noisy work averaged only 0.5 cycles per minute higher than during quiet work. In this series the cessation of all work was followed by a sharp increase in breathing rate, as measured in the two recovery periods; and this occurred without exception throughout the four day-groups.

Because of the great variability of the results on breathing rate, we have made no attempts to carry our analysis of these data further. We may say in conclusion, however, that the kymographic records of breathing rate tended to agree fairly well with the data on ventilation, presented above. The general effect of the noises in practically every case was in the direction of an increased

breathing rate. Though the work itself seemed to be characterized by changes in the opposite direction, it must be remembered that our picture of this process is not complete until we have considered the corresponding changes in amplitude of breathing; and it is to these that we now turn.

6. *Breathing Amplitude*

This process was measured by computing the average height, in millimeters, of the breathing curves within each of the work periods described above. Rather than measure the height of each curve individually, we shortened the procedure by drawing on the kymograph records, two lines, parallel to the time line and to each other; and representing the averages of the extremes of the breathing curves. The distance between these two lines represented approximately the average height of the breathing curves, and this

TABLE 30

Showing Changes in Height of Breathing Curves in mm. on Successive Days in Series A

Date	*Quiet Days*				*Noisy Days*		
	Rest	*Work I*	*Work II*	*Date*	*Rest*	*Work I*	*Work II*
1/13	2.4	2.6	2.4	1/15	1.8	2.1	1.9
1/16	1.7	1.7	2.2	1/17	1.9	2.4	2.0
1/19	1.9	1.9	2.3				
1/20	2.1	1.6	1.7				
1/21	1.9	1.6	1.7	1/22	1.4	2.6	1.8
Av.	2.0	1.9	2.0	Av.	1.7	2.0	1.9
1/23	2.1	3.7	2.8	1/24	1.9	2.0	2.2
1/26	2.1	2.3	2.9	1/27	2.4	2.8	2.8
1/28	2.5	2.1	2.0	1/29	2.1	2.3	2.8
1/30	1.5	1.8	2.3	1/31	2.0	3.5	2.9
2/2	2.7	2.3	2.9				
Av.	2.2	2.5	2.6	Av.	2.1	2.6	2.7
2/4	2.1	2.3	2.5	2/5	2.2	2.9	2.8
2/6	...	...	...	2/7	2.6	4.0	3.3
2/16	2.7	2.9	3.1	2/17	2.9	3.7	3.7
2/18	2.4	3.3	3.5	2/19	3.0	2.9	3.4
2/24	2.8	3.3	2.9	2/25	2.2	3.2	2.9
				2/26	2.3	2.7	2.5
Av.	2.5	3.0	2.7	Av.	2.5	3.2	3.1
2/27	2.5	2.9	2.6	2/28	2.5	2.3	2.7
3/4	2.9	3.3	3.0	3/5	3.0	3.6	3.3
3/6	2.4	2.8	3.3	3/7	2.4	2.2	3.0
3/9	2.5	2.4	2.8	3/10	2.7	3.5	3.2
3/11	2.2	2.8	2.3	3/13	2.7	3.0	2.6
Av.	2.5	2.8	2.8	Av.	2.7	2.9	3.0

procedure was repeated at each point on the records where breathing rates had been counted.

The data on breathing amplitude, thus obtained, are presented in Tables 30–33 for the four series. Figures 61–76 represent these data graphically by day-groups. From the latter we see that the work is generally accompanied by a slight increase in the amplitude of breathing; though there may occur exceptions in individual cases, *e.g.*, in Series C.

The introduction of the noises resulted in an immediate increase in breathing amplitude over the corresponding figures for quiet

TABLE 31

Showing Changes in Height of Breathing Curves in mm. on Successive Days in Series B

Date	*Quiet*	*Quiet*	*Noise*	*Noise*	*Quiet*	*Quiet*
	Rest	*Work I*	*Work II*	*Work III*	*Rec. 1*	*Rec. 2*
3/25	2.7	2.8	3.6	3.4	3.2	......
3/26	2.6	3.2	2.2	3.2	2.5	......
3/27	2.7	3.4	3.4	3.0	5.4	3.2
3/28	2.5	2.3	1.9	2.7	2.6	......
Av.	2.6	3.0	2.8	3.1	3.4	3.2
3/30	3.0	3.7	3.2	3.3	3.2	......
3/31	2.8	4.0	3.0	3.1	......	......
4/1	2.9	3.3	2.8	3.1	2.8	......
4/2	3.4	2.7	3.0	3.8	......	......
Av.	3.0	3.5	3.0	3.3	3.0	......
4/6	2.4	3.4	3.4	3.3	2.8	2.2
4/7	2.4	2.5	2.8	2.9	2.5	......
4/8	2.3	3.4	2.5	2.4	2.6	1.8
4/9	3.0	2.5	2.8	2.8	2.1	2.2
Av.	2.5	3.0	2.9	2.8	2.5	2.1
4/15	2.7	2.6	2.6	3.4	3.2	2.1
4/16	3.4	2.9	2.7	3.0	2.6	2.5
4/17	2.8	3.4	2.4	3.2	3.2	3.1
Av.	3.0	3.0	2.6	3.2	3.0	2.6

TABLE 32

Showing Changes in Height of Breathing Curves in mm. on Successive Days in Series C

Date	*Quiet*	*Quiet*	*Noise*	*Noise*	*Quiet*	*Quiet*
	Rest	*Work I*	*Work II*	*Work III*	*Rec. 1*	*Rec. 2*
4/20	3.4	2.8	3.1	2.9	2.9	3.1
4/21	2.7	3.1	2.7	3.1	3.2	3.1
4/22	3.7	3.2	3.9	3.2	3.2	3.4
4/23	3.3	3.6	4.7	3.9	3.6	2.8

TABLE 33

Showing Changes in Height of Breathing Curves in mm. on Successive Days in Series D

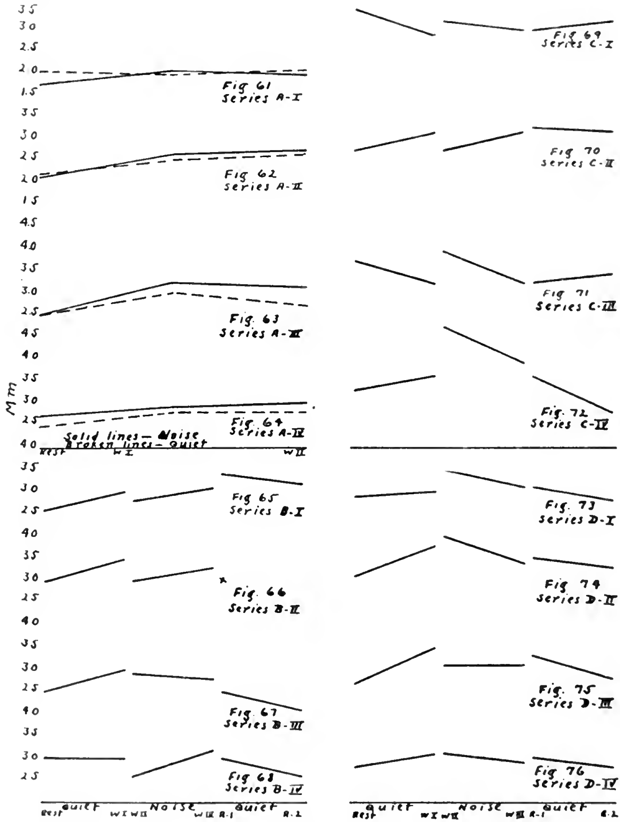
Date	*Quiet*	*Quiet*	*Noise*	*Noise*	*Quiet*	*Quiet*
	Rest	*Work I*	*Work II*	*Work III*	*Rec. 1*	*Rec. 2*
5/11	3.1	2.9	4.5	2.8	2.9	2.9
5/12	3.2	3.0	3.0	3.5	3.1	2.5
5/13	2.3	3.0	4.1	2.9	3.8	3.1
5/14	2.9	3.0	2.7	3.4	2.3	2.4
5/18	2.8	3.0	3.0	2.8	3.3	2.9
Av.	2.9	3.0	3.5	3.1	3.1	2.8
5/19	3.2	3.6	4.4	4.1	2.8	2.5
5/20	3.5	4.1	3.6	3.2	3.4	3.2
5/21	3.5	3.6	4.3	3.4	4.0	3.9
5/22	3.0	4.8	3.5	3.3	3.8	3.7
5/23	2.8	3.6	4.3	3.2	......	3.1
Av.	3.1	3.8	4.0	3.4	3.5	3.3
5/25	2.7	3.6	2.8	3.1	2.7	2.6
5/26	2.8	3.7	3.4	3.1	3.7	2.8
5/27	2.4	2.8	3.0	3.0	3.7	2.5
6/4	2.4	3.5	3.1	3.0	3.2	3.2
6/5	3.2	4.0	3.3	3.5	3.0	2.9
Av.	2.7	3.5	3.1	3.1	3.3	2.8
6/6	2.5	2.9	3.1	3.5	2.5	2.9
6/8	3.4	3.4	2.6	3.0	4.1	2.7
6/9	2.6	3.8	3.5	2.9	3.2	2.7
6/10	2.8	2.4	3.3	2.8	2.3	2.8
Av.	2.8	3.1	3.1	2.9	3.0	2.8

periods. When the subjects were unadjusted to the particular noise under investigation (Series A, C, D) its effect was most pronounced during the first noisy work period; when the subject was partially adjusted (Series B), however, the noise produced a decrease in breathing amplitude during the first noisy work period, followed by a gradual increase during the second. In other words, when the subject was unused to the noise, his tendency was to respond to it with a sudden increase in the depth of breathing, followed by a gradual return to the normal working value; and the progress of adjustment may be traced by noting the decreases in this surplus breathing amplitude. Evidence of adjustment was found throughout the four series, with the possible exception of Series C.

We have confined our description of the changes in depth of breathing wholly to trend comparisons; first because our method of measuring this function was relative rather than absolute; and

second, because of the high degree of variability in the data themselves.

Qualitative descriptions of the breathing curves proved out of the question, as far as throwing any light on the effects of noise



FIGS. 61–76
Showing Changes in Breathing Amplitude in Successive Work Periods by Day-Groups in Series A, B, C, D.

was concerned. The most promising approach would seem to have been the study of changes in the curves, due to articulation. We

were unable, however, to discover any changes which might have been attributed to the noises; chiefly because of the fact that, in order to increase output, the subjects had been encouraged to articulate when adding, under quiet and noisy conditions alike. For these reasons we have not included any data on this head in the present report.

7. *Introspective Reports*

From the day-to-day reports of the subjects regarding their attitude, we classified these responses in three categories; namely, Good, Indifferent, and Bad. Such a classification is almost self-explanatory. By saying that the subject's attitude on any given day was "Good," we meant that he described himself as alert, active, and keenly interested in the task before him. A "Bad" attitude might have been caused by any one of a dozen factors, such as ennui, worry over outside affairs, general "blueness," and the like. An "Indifferent" attitude fell between these two extremes.

When these data were arranged chronologically in the several series, there was noticeable a marked tendency for a given feeling-tone or attitude to persist over a period of from two to five days, approximately. Within this period there might occur wide day-to-day fluctuations in our other measures: in output, accuracy, metabolic rate, etc.; so that attitude could not be regarded as having any significant relationship to the effects of the noise. That is to say that the noise was effective as often when the attitude of the subject was "Good" as when it was "Bad" or "Indifferent," and *vice versa*.[20]

[20] The effects of emotional states upon the resting metabolic rate is another problem entirely; and our present data on this point are to be incorporated in a forthcoming report (31).

V. Discussion

As described above, we found that there was a slight tendency for our noises to retard output, measured in terms of problems worked during a period of twenty minutes. These decreases, however, were small; nor is there any reason for supposing that they would have attained greater significance had the work period been longer. Morgan (25), Ford (12), Laird (22), and Vernon and Warner (39) all used work periods longer than ours, ranging, in fact, from two to four hours; yet their results on this head are in substantial agreement with our own. In regard to accuracy of work under noisy conditions, our data showed a more positive trend than that reported by most investigators cited above. We found definite decreases in accuracy accompanying the noise; decreases, however, which were of short duration, and which were compensated for—in part, at least—by increases during the later sittings of a given series. In both output and accuracy, however, there was evidence of adjustment to the noises on the part of the subjects in every case, regardless of the size of the original noise effects.

The relationship between mental work and metabolic rate comprises in itself a goodly-sized field for research. This problem has been investigated by a number of workers, the studies dating back as far as 1882 (36). Grafe (16) in 1928 published an excellent critical review of the various investigations bearing upon this topic.

Practically all investigators are agreed that mental work is accompanied by very slight changes in metabolic rate. Benedict (4; 5) found rate increases averaging around 5 percent when the muscular movements of his subjects were allowed for. Knipping (19) in 1923 reported results which are in very substantial agreement with our own; even to the extent of finding a tendency for the RQ to be decreased with work. This fact Knipping relates to changes in the phosphoric acid content of the blood. Ilzhoefer (18), avoiding movement on the part of his subjects, found constant increases in metabolic rate accompanying reading; increases which varied from 1.6 percent to 5.1 percent, according to the difficulty of the material read. Laird and Wheeler (20), (23), have made use of a method similar to the one described by us for measuring energy "cost" per unit of mental work. These inves-

tigators, however, fell into the error of supposing that they were measuring "true mental efficiency" and disregarded the part played by concomitant bodily processes.

All things considered, the energy "cost" of mental work must be comparatively slight, even when this work is accompanied by limited bodily movement, such as writing. The net result of such activity is a somewhat higher rate of combustion of the bodily food stores, and a correspondingly slight increase in the generation of heat. It is far from likely that the surplus stores of fat and carbohydrates are drawn upon to meet this demand for added energy; nor is any oxygen debt worth speaking of incurred. The physiological changes with mental work are practically insignificant when compared with those accompanying various kinds of physical work (38).

This, then, is the situation into which the noise is introduced. The effect of the latter is to increase still further the energy expenditure during the work, sometimes as much as 60 percent or more. The net effect, however, is still too slight to have any far-reaching effects upon the general bodily economy; and what effect does appear is soon obscured by the adjustment of the individual to the new situation.

When the effect of the noise is expressed in terms of problems done and compared with corresponding norms for quiet periods, then indeed one finds indications that noise might offer a real problem in our daily lives; were it not for the fact of adjustment. At this point we must remember, however, that a given subject varies greatly in his response to noise from day to day; and we must not be misled in our conception of adjustment by the picture obtained from day-groups alone. Adjustment undoubtedly there is; but it is possible too that other factors may enter in to upset an individual's adjustment on any given day; factors related to his emotional stability, for example.

The results obtained from other investigations of changes in heart rate and breathing, while more variable than those dealing with metabolic rate, are nevertheless in fairly close agreement with our own data. As mentioned above, Schubert (33) found a close correlation between heart rate and metabolism in the case of physical work, just as we did in our own experiment. Chief among those investigators reporting increased heart rate with mental work are Shepard (34); Day (8); Gillespie (15); and Skaggs (35). Skaggs also reports increases in breathing rate from 3 to 4 cycles

per minute, accompanying mental multiplication; while Zoneff and Menmann (40); Angell and Thompson (1); and others have reported decreases among some of their subjects.

Investigations dealing with changes in pulse and breathing accompanying noise have been numerous; and the reader is referred once more to the work of Diserens (9) for a summary of these. Though the data are often variable and conflicting there seems to be a general tendency for noise to accelerate these processes to a greater or a lesser extent; depending to some degree, however, upon the nature of the stimuli, and the direction of the subject's attention. In all of the studies reported, one notes that the question of adjustment is neglected by the investigators.

VI. Summary and Conclusion

1. Experiments with two subjects have shown that mental work together with its physical concomitants is accompanied by small but consistent increases in metabolic rate; heart rate; and breathing rate and volume. When complex noises, ranging in intensity from 55 to 65 decibels, are added to the situation further increases in these values are observable at first.
2. The increases in the working values caused by the noises may run as high as 60 percent or more during the first days of an experiment; and they are most marked during the first periods in which noises are present.
3. When the subject is presented with the same situation day after day, over a period of several weeks, the noise effects gradually disappear, and the working values tend to return to normal.
4. Adjustment to the noises tends to appear first in those work periods which showed the greatest initial effect of the noise, and last in the subsequent work periods.
5. When the subject has become adjusted to a particular kind of noise or to a special manner of presentation of this noise, a change of either will result in a repetition of the adjustment process, though on an abbreviated scale.
6. The effects of the noises tend to carry over to a small extent into the recovery periods following cessation of the work; and here, as elsewhere, the process of adjustment may be traced.
7. When the increase in energy expended during the work is related to units produced, the effect of the noise is still further emphasized; though the fact of adjustment tends to limit the significance of the effect.
8. In the present study, no correlation was found between the attitude of the subjects and the effects of the noise.
9. No study of the effects of noise can be considered adequate unless account is taken both of the day-to-day variability of an individual's response, and the possibility of adjustment to the noise. At their first introduction, the noises represented a new factor in the subjects' environment, and one to which they must needs adapt themselves. The accomplishment of this resulted in a temporary impairment of efficiency and a correspondingly greater tax upon the organism. The progress of this adjustment is controlled by the same factors

which govern an individual's adaptability in other situations; and it is related in part to his variability from day to day. The extent to which noise effects and adjustment are dependent upon the quality and quantity of the noises themselves must be determined by future investigators.

Bibliography

1. Angell and Thompson. Organic Processes and Consciousness. *Psych. Rev.*, 1899, 6, 32–73.
2. Bailey, C. V. A Low Resistance Air Valve. *Proc.* Soc. Exp. Biol. Med., 1926, 24, 184–5.
3. Bailey, C. V. Notes on Apparatus Used in Determining Respiratory Exchange in Man. *J. Biol. Chem.*, 1921, 47, 277–83.
4. Benedict, F. G. The Influence of Mental and Physical Work on Nutritive Processes. *Proc.* Am. Phil. Soc., 1910, Vol. 49, No. 195, 143–63.
5. Benedict, F. G., and Carpenter, T. M. The Influence of Muscular and Mental Work on Metabolism. U. S. Ag. Exp. Station Bull., 1909, pp. 208.
6. Boas, E. P. The Cardiotachometer. *Arch. Int. Med.*, 1928, 41, 403.
7. Boothby, W. M., and Sandiford, I. A Laboratory Manual of the Technique of Basal Metabolic Rate Determinations. Phila., 1920, Saunders, pp. 111.
8. Day, M. E. The Influence of Mental Activities on Vascular Processes. *J. Comp. Psych.*, 1923, 3, 333–78.
9. Diserens, C. M. The Influence of Music on Behavior. Princeton Univ. Press, 1926, pp. 210.
10. Douglas, C. G. A Method for Determining the Total Respiratory Exchange in Man. *Proc.* Physiol. Soc. Lond., *J. Physiol.*, 1911, 42, 17–18.
11. DuBois, E. F. Basal Metabolism in Health and Disease. Phila., 1927, Lea and Febiger, 431 pp.
12. Ford, A. Attention-Automatization: an Investigation of the Transitional Nature of Mind. *Am. J. Psych.*, 1929, 41, 1–32.
13. Free, E. E. Practical Methods of Noise Measurement. *J. Acoust. Soc. Amer.*, 1930, 2, 18–19.
14. Garrett, H. E. Statistics in Psychology and Education. New York, Longmans Green, 1926, pp. 317.
15. Gillespie, A. D. The Relative Influence of Mental and Muscular Work on the Pulse-Rate and Blood Pressure. *J. Physiol.*, 1924, 58, 425–32.
16. Grafe, E. Der Stoffwechsel bei Psychischen Vorgängen. In Handbuch der Normalen und Pathologischen Physiologie. Bd. V, Stoffwechsel und Energiestoffwechsel. Berlin, J. Springer, 1928, 199–211.
17. Hawk, P. B., and Bergeim, O. Practical Physiological Chemistry. Phila., P. Blakiston's Son & Co., 1931. pp. 929.
18. Ilzhoefer, H. Ueber den Einfluss Geistiger Arbeit auf den Energieverbrauch. Arch. f. Hygiene, 1924, 94, 317–28.
19. Knipping, H. W. Respiratorischer Gaswechsel, Blutreaktion und Blutphosphorsaürespiegel bei Geistiger Arbeit. *Zeit. f. Biol.*, 1923, 77, 165–74.
20. Laird, D. A. Effects of Loss of Sleep on Mental Work. *Indust. Psych.*, 1926, 1, 427–8.
21. Laird, D. A. Experiments on the Physiological Cost of Noise. *J. Nat. Inst. Indust. Psy.*, 1929, 4, 251–8.
22. Laird, D. A. The Measurement of the Effects of Noise upon Working Efficiency. *J. Indust. Hygiene*, 1927, 9, 431, ff.
23. Laird, D. A., and Wheeler, W. What it Costs to Lose Sleep. *Indust. Psych.*, 1926, 1, 694–6.
24. Morgan, J. J. B. The Effects of Sound Distraction Upon Memory. *Am. J. Psych.*, 1917, 28, 191–208.

25. Morgan, J. J. B. The Overcoming of Distraction and other Resistances. *Arch. Psych.*, 1916, No. 35, pp. 84.
26. New York Health Department, Noise Abatement Commission. City Noise. New York, 1930, pp. 308.
27. Poffenberger, A. T. Applied Psychology, Its Principles and Methods. New York, Appleton, 1927, pp. 586.
28. Poffenberger, A. T. Effects of Continuous Work on Output and Feelings. *J. Appl. Psych.*, 1928, 12, 459–67.
29. Poffenberger, A. T. The Effects of Continuous Mental Work. *Am. J. Psych.*, 1927, 39, 283–96.
30. Poffenberger, A. T., and Rounds, G. H. Article in Preparation.
31. Poffenberger, A. T., Rounds, G. H., Schubert, H. J. P., and Harmon, F. L. Variations in Metabolic Rate at the State of Physical Rest. In Preparation.
32. Rounds, G. H., and Poffenberger, A. T. The Measurement of Implicit Speech Reactions. *Am. J. Psych.*, 1931, 43, 606–612.
33. Schubert, H. J. P. Energy Cost Measurements on the Curve of Work. *Arch. Psych.*, 1932, 139, pp. 62.
34. Shepard, J. P. Organic Changes and Feeling. *Am. J. Psych*, 1906, 17, 522–84.
35. Skaggs, E. B. Studies in Attention and Emotion. *J. Comp. Psych.*, 1930, 10, 375–419.
36. Speck. *Arch. f. Exp. Path.*, 1882, 15, 81 ff.
37. Thorndike, E. L. The Curve of Work and the Curve of Satisfyingness. *J. Appl. Psych.*, 1917, 1, 265–80.
38. Tigerstedt. Lehrbuch des Physiologie des Menschens. Leipzig, 1919.
39. Vernon, H. M., and Warner, C. G. Objective and Subjective Tests for Noise. *Person. J.*, 1932, 11, 141–9.
40. Zoneff und Meumann. Ueber die Begleiterscheinungen Psychische Zustände. *Phil. Stud.*, 1901, 18, I, 1–113.

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